ON THE CONSTRUCTION OF HOOPED CANNON: BEING A SEQUEL TO A MEMOIR "ON THE PRACTICABILITY OF CONSTRUCTING CANNON OF GREAT CALIBER, ETC"

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649265237

On the Construction of Hooped Cannon: Being a Sequel to a Memoir "On the Practicability of constructing cannon of great caliber, etc" by Daniel Treadwell

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

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DANIEL TREADWELL

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Trieste

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BEING

A SEQUEL TO A MEMOIR

"ON THE PRACTICABILITY OF CONSTRUCTING CANNON OF GREAT CALIBER, ETC.,"

PUBLISHED IN THE

MEMOIRS OF THE AMERICAN ACADEMY, IN THE YEAR 1856.

BY

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FROM THE MEMOIRS OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES, 1864.

BOSTON:
LITTLE, BROWN, AND COMPANY.
1864.

ON THE

CONSTRUCTION OF HOOPED CANNON.

[From the Memoirs of the American Academy of Arts and Sciences, 1864.]

ALTHOUGH a great improvement has been made in the construction of cannon by the adoption of the principle, and imperfectly the mechanical form, indicated by me in a Specification of June 19th, 1855, which was immediately afterwards expanded into the Memoir published in the VIth Volume of the Academy's Memoirs;* still, many points in the theory of that construction remain not only unperfected, but almost unexamined.

It is my purpose, therefore, in this paper, to investigate several important properties and laws which are inherent in the materials of which the gun described in my former memoir is constructed; and from this investigation I shall endeavor to draw such instruction as will enable us, if not to perfect,

* The memoir in the VIth Volume must be considered as a sequel to, and a further development of, the principles contained in a publication, in the form of a pamphlet, made by me in 1845. In this pamphlet, not only the principles, but the method of construction since followed by Armstrong and others, are fully pointed out.

at least to understand and improve, the theory of construction. The investigation will be founded almost entirely upon certain peculiarities in the nature, character, and properties of the materials (wrought-iron, cast-iron, and steel) of which the guns, constructed upon the principle heretofore published by me, are formed.

With these preliminary remarks I enter at once into the proposed inquiry, leaving the development of the course to be pursued to appear as I proceed.

In the memoir of 1855, before referred to, in giving an account of the theory of hooping cannon, I inserted the following paragraph (p. 10):

"There may, at the first view, seem to be a great practical difficulty in making the hoops of the exact size required to produce the necessary compression. This would be true if the hoops were made of cast-iron, or any body which fractures when extended in the least degree beyond the limit of its elasticity. But wrought-iron and all malleable bodies are capable of being extended without fracture much beyond their power of elasticity. They may, therefore, be greatly elongated without being weakened. Hence we have only to form the hoops *small in excess*, and they will accommodate themselves under the strain without the least injury."

And again, in a note, I said: "Mr. Barlow does not limit the application of his investigation to any kind of material, but it is evident that his conclusions are not applicable to any *malleable* metal like bronze; for in a cylinder constructed of hoops of this material, the inner hoops may be elongated by the pressure acting as a *crushing* force, and by this means be enlarged without any diminution of tenacity. Perhaps some kinds of soft cast-iron may accommodate themselves to an enlargement in the same way. But with hard crystalline cast-iron, no actual displacement of the constituent particles can take place without fracture; and although the effect of the fluid as a crushing force may act as an auxiliary to the strain, as any estimate of its amount would be a mere guess, I shall not attempt any modification of Mr. Barlow's conclusion, when applied, as in this case, to hard cast-iron gun-metal."

However important I might have considered the effects of the crushing force, and the partial or imperfect malleability of cast-iron, by which the gun may be permanently distended, a further examination of the subject has convinced me, that Mr. Barlow's theory must be in all cases modified and limited by the elongation or yielding from this malleability under the crushing pressure of the fluid; and, in many cases, as where the material is bronze or wrought-iron, the whole theory must be discarded as inapplicable. To show this, I will state the following experiment. I took a ring or hoop of wrought-iron, made up of four concentric rings, one placed over another, after one of the methods practised by me in making my wrought-iron guns in 1840–1843. These rings, when welded together, formed a hollow cylinder 1 inch long, having an internal diameter of

$1\frac{1}{2}$ inches, and an external diameter of 3 inches; consequently its walls were $\frac{3}{4}$ of an inch thick. This cylinder, after being smartly hammered or sledged when cold, was subjected to distension by driving into it a conical plug or pin, by blows with a heavy sledge. By this means the inside diameter was increased to $2\frac{1}{8}$ inches. This distension, from $\frac{12}{8}$ to $\frac{17}{8}$, was far from rupturing the ring, although it produced a great number of minute fissures upon the outside, while the inside did not show the least sign of crack or flaw.

I should remark, that this ring was made of very tough Norway iron; but, although I made several others in the same way, and of common English as well as of American iron, none of them broke under the strain before a distension of $\frac{1}{10}$ of their inside diameter; and, in all cases, the fracture commenced upon the outside and worked gradually inward to the caliber.

Another thing, worthy of all attention, was this: The end of each cylinder or ring showed, after welding, the thickness of each of the several concentric rings of which it was formed; and after the distension, the greater diminution of thickness in the inner and smaller rings was very apparent; thus showing how much greater was their distension or elongation, circumferentially, than that of the rings outside of them; and furnishing an experimental exemplification and corroboration, if such corroboration were required, of the fact first geometrically demonstrated by Barlow, and upon which he founded his theory explaining the weakness of cast-iron hollow cylinders when exposed to an internal pressure. Now, although the fact is to be received as he has demonstrated it, yet it becomes evident that the theory and formulas founded upon it must be limited, rigidly, to unmalleable bodies, and is in nowise applicable to cylinders of wrought metal, like the rings or hoops experimented upon by me. For, to bring a case under the conditions or facts supposed to operate in that theory, the fracture must begin upon the inside, which is supposed to be distended, like a rod strained by a suspended weight. But, in my experiments, not only was the innermost part of the cylinder subjected to the straining force of the conical pin, tending to rupture the whole thickness of the cylinder, but the inner portion of it, to a certain depth outward, was placed between two opposing forces, viz. the pressure of the conical pin in one direction, and the binding strength of the external portion of the cylinder in the other. Between these two forces it was crushed or pressed and extended laterally, and thus made thinner and longer, as a bar or sheet of metal is under a hammer, or between the rollers of a mill. Under these conditions it could not fracture before the external portion; for, to fracture a body, its integrant atoms or molecules must be separated; but in this case they were pressed together. This crushing pressure of the conical plug differed in no essential form from that produced by fired gunpowder. So the fracture commencing upon the outside of the ring is similar to that made in the bursting of bronze guns, which always commences upon the outside. The same fact was observed by me, twenty years ago, in the trial, to extremity, of two 32-pounder wrought-iron guns. In both of these, the fracture began upon the outside and worked slowly inwards.

The preceding statement cannot fail, I think, to convince any one that Mr. Barlow's theory is wholly inapplicable to guns made of wrought-iron, or any like malleable material, and, indeed, is to be applied, in its complete and unlimited extent, only to such materials as highly hardened steel, glass, and those crystalline or wholly unyielding bodies, in which the ultimate particles or molecules are incapable of being made to change place permanently in relation to each other, but in which the limit of elasticity ends in complete separation or fracture. When applied to hollow cylinders made of substances of this latter kind, it is probably true to the letter. But what is cast-iron? And are we to be guided by Barlow's theory in computing the strength of cannon made of this material? Believing, as I do, that most kinds of cast-iron are, to some, though a very limited extent, malleable, or, at least, that they admit of some small permanent change of form without fracture, we ought not, in my judgment, to apply Barlow's theory, without some modification, to express the strength of guns made of such material, as they really possess greater strength than the formula given by that theory assigns them; though for many of the harder and completely crystalline kinds