Learning from Stradivarius

Chris Wise
Expedition Engineering
and University College, London
Meaning what?...
7 years later…
Awarded to
C. M. Wise
for
The S. Arbury Prize for Cricket
1974

S. Balle
Headmaster
Another 25 years later...
via?
1828
Description of a Civil Engineer

By Thomas Tredgold Esq. F.R.S.

Civil Engineering is the art of directing the great sources of Power in Nature for the use and convenience of man.
...FORCES OF NATURE....

....FOR THE USE AND CONVENIENCE OF MAN
thank you

Thomas
HEAD WRIGHTSON & Co.
N°21
TEESDALE IRON WORKS
STOCKTON ON TEES
1870
“I remember when all this used to be Wrightson’s Steel,
I worked on it as a lad, when they had the contract to get the scrap off here, when they pulled everything out.”
The acid test
“It’s got better metal than the other bridges.”
“It’s a lovely way to spend your lunchtime.”
“if you’d seen the people, it says it all.”
10,000 Hours

(Malcolm Gladwell: Outliers)
Five stage model of learning
1980:
Stuart and Hubert Dreyfus
University of California

Novice:
Competence:
Proficiency:
Expertise:
Mastery
amo amas amat

Aubrey Gerald Scrase
"So by the time they returned to England from Hamburg, they sounded like no one else. It was the making of them."

Beatles' biographer Philip Norman
What are they doing?
artists,
artisans
philosophers
An Artist’s Strategy

Motivated by interest
Finds it easy to start, hard to stop
An Artisan’s Strategy

Seeks perfection of form
Can’t begin without a pre-existing concept then incrementally seeks improvement.
A Philosopher’s Strategy

Seeks meaning
Finds it hard to start
because needs perfection of meaning first
Our Velopark proposal is about cycling before all else...... this is not about flights of architectural fantasy or wonders of structural gymnastics......
“the illusion ... we exaggerate how knowable the world is”
Nothing to do with me - it's the supporting structures!
Tony Fitzpatrick: Engineer, Arup, d. 2003
Testing testing

(what are the limits of performance?)
An analysis of the forces required to drag sheep over various surfaces

J.T. Harvey\textsuperscript{a,*}, J. Culvenor\textsuperscript{b,1}, W. Payne\textsuperscript{c}, S. Cowley\textsuperscript{b}, M. Lawrance\textsuperscript{c}, D. Stuart\textsuperscript{d}, R. Williams\textsuperscript{c}

\textsuperscript{a}School of Information Technology and Mathematical Sciences, University of Ballarat, P.O. Box 663, Ballarat, Victoria 3353, Australia
\textsuperscript{b}VIOSH Australia, University of Ballarat, P.O. Box 663, Ballarat, Victoria 3353, Australia
\textsuperscript{c}School of Human Movement and Sport Sciences, University of Ballarat, P.O. Box 663, Ballarat, Victoria 3353, Australia
\textsuperscript{d}School of Physical Education, Exercise and Sport Studies, University of South Australia, Holbrooks Road, Underdale, South Australia 5032, Australia
\textsuperscript{e}Wimmera Health Care Group, Physiotherapy Department, Baillie Street, Horsham, Victoria, Australia, 3400

Received 26 September 2001; accepted 8 July 2002

Abstract

Some occupational health and safety hazards associated with sheep shearing are related to shearing shed design. One aspect is the floor of the catching pen, from which sheep are caught and dragged to the shearing workstation. Floors can be constructed from various materials, and may be level or gently sloping. An experiment was conducted using eight experienced shearers as participants to measure the force exerted by a shearer when dragging a sheep. Results showed that significant changes in mean dragging force occurred with changes in both surface texture and slope. The mean dragging forces for different floor textures and slopes ranged from 359 N (36.6 kg) to 423 N (43.2 kg), and were close to the maximum acceptable limits for pulling forces for the most capable of males. The best floor tested was a floor sloped at 1:10 constructed of timber battens oriented parallel to the path of the drag, which resulted in a mean dragging force 63.6 N (15\%) lower than the worst combination.

© 2002 Elsevier Science Ltd. All rights reserved.
Slope 1:10 (5.6deg)
VITRUVIUS

XI


2. Nam quae sunt in capitebus foramina, per quorum spatia contenduntur capillo maxime muliebri vel nervo fuges, magnitudine ponderis lapidis, quem debet ea ballista mittere, ex ratione gravitatis proportione sumuntur, quedinmodum catapultis de longitudinalibus sagittarum. Itaque ut etiam qui geometricorum non noventur, habeant, aexpeditum, ne in periculo belli cogitationibus detineantur, quae ipse faciendo certa cognovi quaecumque ex parte accepta praceceptoribus, suanda exponam, et quibus rebus Graecorum pensiones ad modulos habeant rationem.

BOOK X. C. XI.

CHAPTER XI

ON BALLISTA

1. I have described the design of a catapult and the details which are combined in accordance with proportion. The design of the ballista varies and its differences are adjusted for the purpose of a single effect. For some are worked by levers and windlasses, some by many pulleys, some by capstans, some by wheels. Yet all ballistas are constructed with a view to the proposed amount of the weight of the stone which such a machine is to let fly. Therefore only those craftsmen who are familiar with the geometrical treatment of numbers and their multiples.

2. For the holes which are made in the frames (through the openings of which ropes are stretched, made especially of woman’s hair or of the sinews of animals) are taken proportionately to the amount of the weight of the stone which the ballista is to shoot, in accordance with gravity, just as in the case of catapults the length of the arrows furnishes the module. Therefore in order that persons who are ignorant of geometry may be equipped and may not be delayed by calculation amid the perils of war, I will specify in accordance with my own knowledge gained in practice and also in accordance with the instructions of my teachers. Further, I will set forth in detail the manner in which the Greek mathematicians which other mathematicians could only solve by analysis of a numerical character.

3. Euclid treats numbers geometrically, Books VII–X. It has been said of Newton that he could treat geometrically.
2. For the holes which are made in the frames (through the openings of which ropes are stretched, made especially of woman’s hair or of the sinews of animals) are taken proportionately to the amount of the weight of the stone which the balista is to shoot, in accordance with gravity, just as in the case of catapults the length of the arrows furnishes the module. Therefore in order that persons who are ignorant of geometry may be equipped and may not be delayed by calculation amid the perils of war, I will specify in accordance with my own knowledge gained in practice and also in accordance with the instructions of my teachers. Further, I will set forth in detail the manner in which the Greek problems which other mathematicians could only solve by analysis of a numerical character.
Intermission: a cautionary tale which would shock Stradivarius
...as we all know: Energy is getting more expensive....
Materials have to go further to meet rising populations and standards of living....
Labour is comparatively cheaper (or we’re replaced by robots)....
and designers, engineers, scientists from 20 countries
each find ways
to use materials better to design
driving
out the embodied carbon
equivalent to driving
50 billion car miles
20 countries together could save the carbon equivalent of not driving a Trillion Miles.
Suggested Units:
10 billion car miles = 1 Clarkson
100 Clarksons = 1 Trump
= 1 Trillion car miles
(a mind-bogglingly extravagant quantity of energy)
100 Clarksons = 1 Trump
Saving a Trillion miles of embodied carbon:
Wouldn’t that be something??
...but, a Trillion miles?

what can a humble designer do?
as an example, take one industry:

“Buildings”
where even a simple 9m office beam like this weighs 735 kg
so here’s a new one (which the industry won’t make for us)
now only 513 kg

that's 30% lighter
Here’s a 10 storey trad steel building
And here’s its “perfect beam” equivalent
Here’s the steel that is always wasted
A ridiculous global waste of, say, 30 million tonnes of steel each year...

The carbon equivalent of not driving 120 billion miles....
...enough energy to boil 700 cups of tea for everyone on the planet...
No matter how wonderful the materials, if designers and manufacturers won’t work together to make them economically viable........
Inertia rules
And it has been scientifically proven that it’s always someone else’s responsibility……….
car miles in the steel structure: 79 million
8 years later: Beijing 2008
725 million car miles
Carbon stickers for buildings??
with only the back-of an envelope...
...we can save more and more

**CALCULATIONS**

**JOB NO.**

**PAGE**

**DATE**

**EXPEDITION**

**SAVINGS**

**UK**

**EMBODIED**

**CO₂**

**MEGATONNES**

**STEEL**

**CONCRETE**

**TOTAL**

---

**REARRANGING DEFLECTION LIMIT.**

- Sec unlimited, $\delta_{ul} < L/360$

\[
I_{\text{max beam}} = 1210 \text{ cm}^4
\]

\[
W_{\text{max beam}} = 2953 \text{ cm}^3
\]

\[
I_{\text{max beam}} = 12690 \text{ mm}^4
\]

\[
W_{\text{max beam}} = 30193 \text{ mm}^4
\]

\[
\text{UBB 457 x 152 x 60} \quad \text{UBB 610 x 229 x 113}
\]

**MATERIAL QUANTITIES:** 2.64 T

- Sec unlimited, $\delta_{ul} < L/300$

\[
I_{\text{max beam}} = 1210
\]

\[
W_{\text{max beam}} = 10.5
\]

\[
I_{\text{max beam}} = 10.5
\]

\[
W_{\text{max beam}} =
\]

\[
\text{UBB 545 x 152 x 60} \quad \text{UBB 610 x 229 x 113}
\]

**MATERIAL QUANTITIES:** 2.64 T

- Sec unlimited, $\delta_{ul} < L/200$

\[
100 \text{mm}
\]
...each scribble saves more...
... and more....

10 BILLION CAR MILES

**#2 Influence of Case Safety Factor**

Divide load factors by 1.2 to get rid of components linked to quality of workmanship and analysis.

\[ ULS = 1.125 \times DL + 1.25 \times IL \]

- **I** Beam
  - \[ W_{a,y} = 916 \text{ cm}^3 \]
  - \[ I_{a,y} = 70.17 \text{ mm}^4 \]
  - \[ ULS = 0.45 \times 150 \times 52 \]

- **I** Beam
  - \[ W_{a,y} = 2460 \text{ cm}^3 \]
  - \[ I_{a,y} = 16774 \text{ mm}^4 \]
  - \[ ULS = 0.45 \times 150 \times 52 \]

**#3 Influence of Lighter, Use Less**

Use values from structural study

\[ IL = 1.06 \text{ kN/m}^2 \]

- **I** Beam
  - \[ W_{a,y} = 668 \text{ cm}^3 \]
  - \[ I_{a,y} = 2976 \text{ mm}^4 \]
  - \[ ULS = 0.40 \times 60 \times 35 \]

- **I** Beam
  - \[ W_{a,y} = 1792 \text{ cm}^3 \]
  - \[ I_{a,y} = 7113 \text{ mm}^4 \]
  - \[ ULS = 0.40 \times 60 \times 35 \]

**Material Quantities**

- **Steel**
  - 30%\n  - Material quantities: 1.74 T

- **Concrete**
  - Material quantities: 1.22 T
and more...
those four little design steps save
10 billion car miles
in a single year
just in the UK
how about bog-standard concrete floors (shaped by genetic algorithms)?
that’s another

10 billion miles
designed out
the Stradi-velodrome
We wondered if we could do it
…with the lightness of an airship
....airship plus the technology of spiders
....and the craftiness of the Welsh
car miles: 43 million
car miles:
7 million
What is there to learn from Stradivarius?

(and from Cathedrals....)
What is there to learn from Stradivarius?

Understand your materials
What is there to learn from Stradivarius?

Respect the laws of nature
What is there to learn from Stradivarius?

Master your tools
What is there to learn from Stradivarius?

Design from the inside out
What is there to learn from Stradivarius?

Design by performance not regulation
What is there to learn from Stradivarius?

Be a good apprentice
What is there to learn from Stradivarius?

Devote 10,000 hours if you want to develop mastery.