The Lazy Bridge – Partial Self-balancing
Liam J D Wadsworth

<u>**Structure to be analysed:**</u> Gateshead Millennium Bridge, Newcastle

<u>**Concept:**</u> Partial Self Balancing

"A self balancing structure has a geometry that permits the forces in the structure to be balanced internally (or partly balanced), resulting in a reduction of forces in structural members and/or reactions in structural foundations." [1]

The Gateshead millennium bridge uses partial self- balancing by positioning its two main components, the arch and the deck, on opposite sides of a common pivot point. This means that each of the components creates a moment in the

Figure 1 : Gateshead Millennium bridge [F1]

opposite direction and thus the two moments oppose each other. This in turn reduces the amount of work required to open the bridge allowing river traffic to pass underneath it.
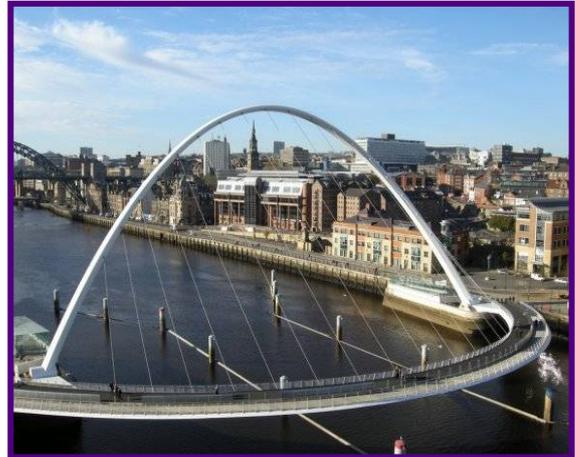
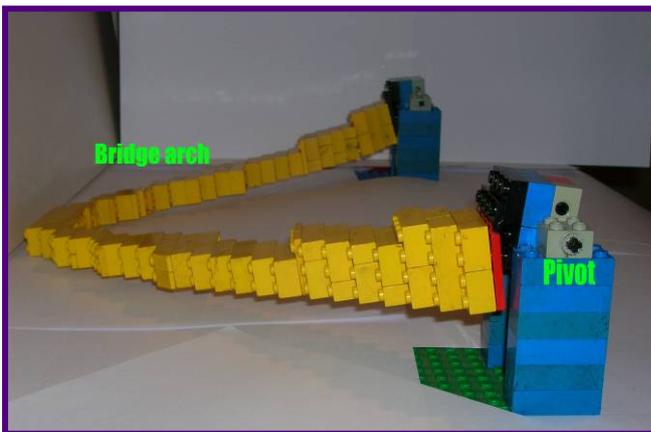<u>**Model**</u> To display this concept a Lego model was built at a scale of 1:200.

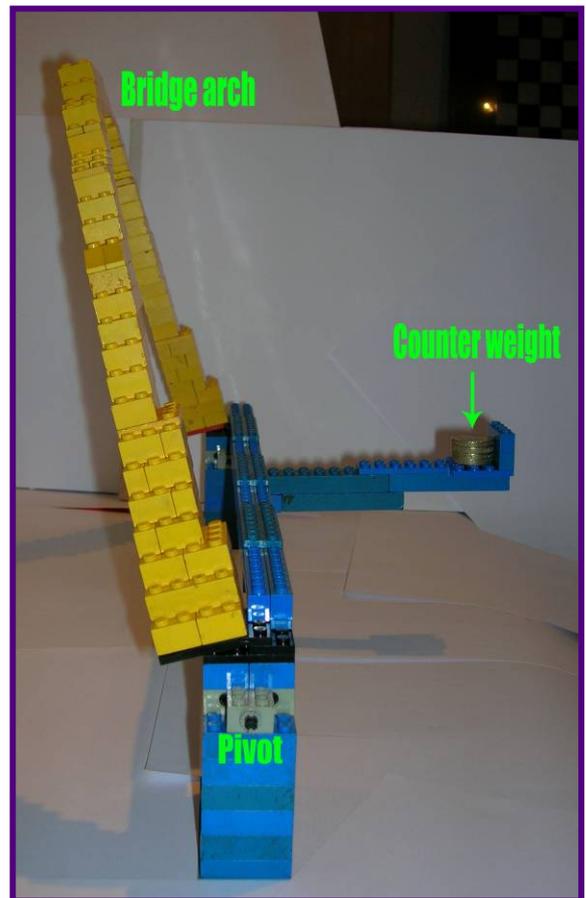**Figure 2 (above) : Arch alone (natural position)** [own work]

Figure 3 (right) : Arch balanced [own work]

In figure 2 the bridge arch is laying in its natural position (in the river). To get the arch to rest in its balanced position an equal and opposite moment must be applied, in this case four £1 coins as seen in figure 3 (individual mass of 9.35g).

Mass of £1 coins = 4 x 9.35 = 37.40g
Moment created by the arch alone
= 0.12 x (0.03740 x 9.81)
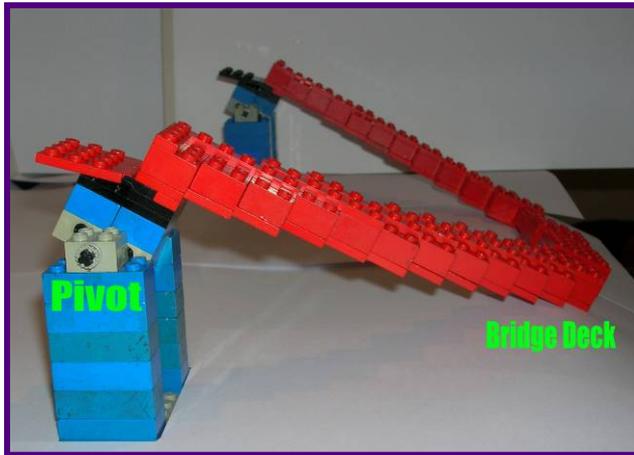= 0.044 Nm (Anti-clockwise)

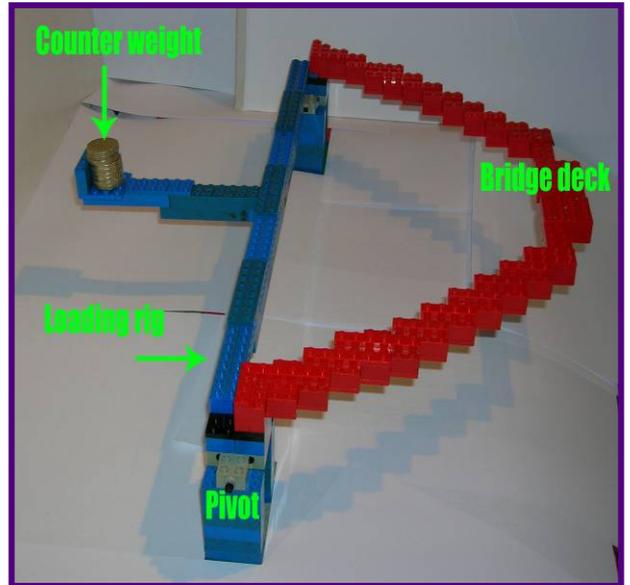**Figure 4 (right) : Deck balanced** [own work]

Figure 5 (above) : Deck alone (natural position) [own work]

In figure 4, the bridge deck is laying in its natural position (in the river). Again an equal and opposite moment is required to get the deck to rest in its balanced position, in this case nine £1 coins. (figure 5)

Mass of £1 coins = 9 x 9.35 = 84.15g
Moment created by the deck alone = 0.12 x (0.08415 x 9.81)
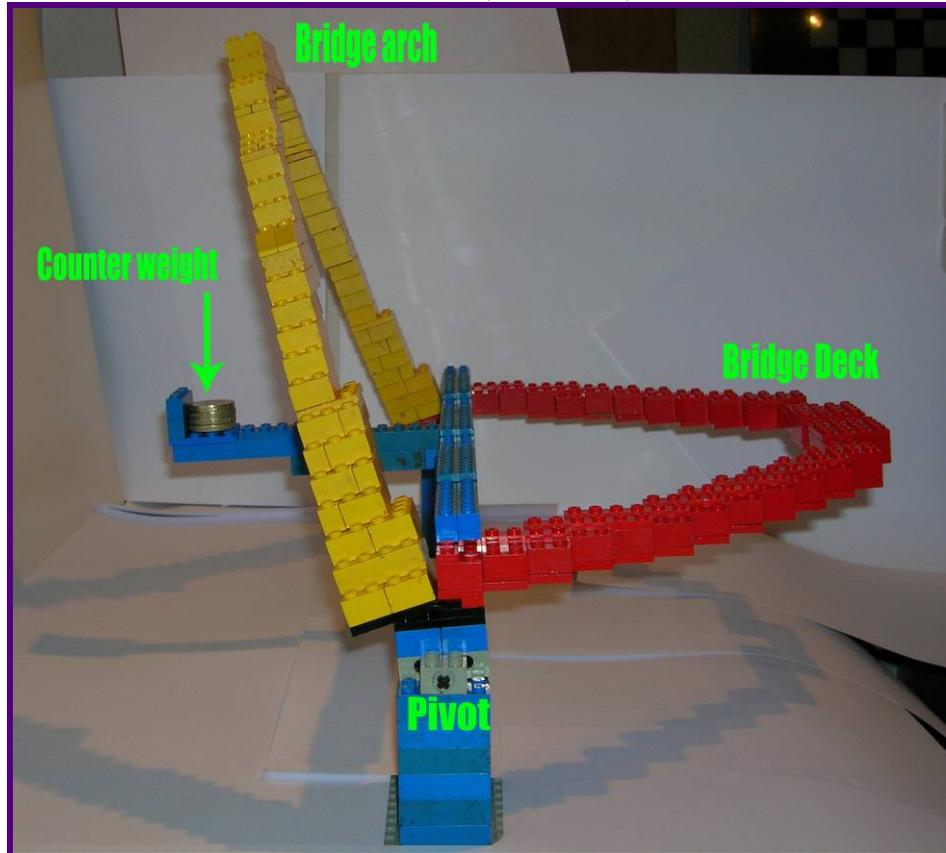$$= 0.099 \text{ Nm} \text{ (Clockwise)}$$

Figure 6 : Complete model in balanced position [own work]

With the model bridge fully assembled (figure 6), the effects of partial self balancing are clearly seen, only four £1 coins are required to balance the bridge.

Mass of £1 coins   = 4 x 9.35 = 37.40g
Moment created by the arch alone   = 0.12 x (0.03740 x 9.81)
                                                                      = 0.044 Nm (Clockwise)

0.044 Nm is only 30% of the moment required to balance the two bridge components separately. This is best shown graphically

Figure 7 : Coins required to balance the model [own work]

As shown in figure 7 to balance the two parts of the bridge separately thirteen coins are required but to balance the complete bridge only four are required. This reduction is achieved purely by the positioning of the bridge components and is partial self-balancing.

In real terms the partial self balancing allows the Gateshead Millennium Bridge to complete a rotation at the cost of only £3.60 in electricity and requires only 10 000kN of force [2]. This is massively impressive considering that the bridge weighs 781 tonnes.

Sources

[1] - Passive control system
   Tran, 1998
[2] - The Structural Engineer Vol. 79 / No 3 6 February 2001, Paper: Clarke / Eyre,
    Page 30 – 35
[3] - http://www.engagingplaces.org.uk/resources/art63641
   Accessed 07-09-2009

Figure 1 (F1): http://pricetags.files.wordpress.com/2009/01/millenium-bridge-newcastle.jpg
Figures 2 – 7 : Own work