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THE ROLLOUT STRESS RIBBON BRIDGE

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Summary

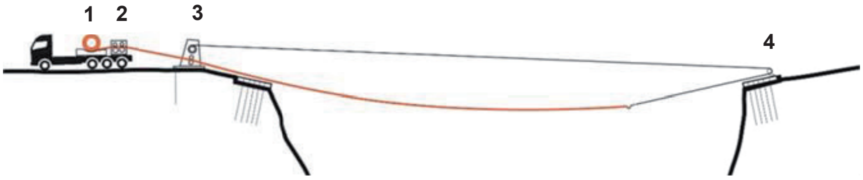
Stress ribbon bridges are light and visually elegant. At sites with solid conditions for tension based anchoring, they can also be very economical. This paper presents the concept of a roll-out stress ribbon bridge where the load-carrying element is a plane deck plate. By the principle of rolling the entire bridge deck to a coil at a steel-mill and un-coiling on site, stress ribbon footbridges can be built with minimal construction on site. The coiled bridge-deck can easily be transported on one truck and the construction can be done without heavy vehicle access to both ends of the bridge. This paper suggests how to launch this type of bridge and discusses some basic material as well as structural properties regarding static and dynamic performance. Similarly to stress ribbon bridges in general, basic design criteria relate to anchoring the horizontal forces at abutments and to dynamic properties in relation to pedestrians. In addition, the Rollout Bridge has some particular design issues related to the procedure of un-coiling and to pulling the bridge deck over the span. As the bridge deck is heavier than the tension elements in bridges where tension elements and bridge deck are separate, the horizontal forces during construction requires more attention. Briefly analysing some alternatives concerning span length and slope at abutments indicates that the concept is promising and worth further studies in tuning geometry, materials and weights and developing more explicit design of a bridge to be constructed in real.

Keywords: stress ribbon bridge; roll-out bridge; coiled steel plate bridge

The roll-out bridge concept

> *Yet it is also true, most profoundly true, that in the most pure aesthetic emotion (as in so many other things in life) simplicity is a virtue. Hence, beauty is now sought within a minimum of elements: all of them essential.* [1]

In most kinds of design, beauty is related to solving the task by as few and essential elements as possible. From such an approach, this paper describes the principle for a stress ribbon bridge that except from handrails and abutments consists of only one element: a continuous steel-plate, resulting in a bridge being as simple as it can possibly be. Such a bridge with a cross section of 1500 x 10 mm and 30 m long weights approximately 20 kN implying the coil being easily transported. The peculiarities of the Rollout Bridge compared to other stress ribbon bridges relate to the procedure of un-coiling and the higher weight (due to the entire bridge being the tension element) and therefore the higher tension to be handled during launching on site. Unless tiny bridge or very large and heavy truck, these two issues together imply a need for a pulling and braking unit firmly anchored to ground during launching the bridge plate. Figure 1 illustrates construction on site.



Legend:
***1:** coiled plate*
***2**: un-coiler*
***3:** pulling and braking unit*
***4:** wire block*

Fig. 1, Launching procedur. Figure by Vidar Vollan

To exemplify the sensitivity of the concept some alternative lengths and slopes are examined, which consequently influence the mid-point sag, the tension force and thus the natural frequencies. The stress levels for a bridge deck given a thickness of 10 mm and a width of 1.5 m and a length of 30 m assuming a steel density of 7850 kg/m3 and a service load of 5 kN/m2 will be roughly 110 MPa. That is, about ½ to ⅓ of the yield stress depending on final choice of steel. Some further results are presented in Table 1. showing the estimated range of possible frequency tuning based on a simple sinusoidal mode shape function.

Table 1. Variation in structural parameters vs slope and length

	slope 1/20	slope 1/12
Results for:	15m / 30m / 50m	15m / 30m / 50m
f_{V1} [Hz]	1.28 / 0.91 / 0.70	1.00 / 0.70 / 0.54
f_{H1} [Hz]	14.3 / 3.66 / 1.46	14.1 / 3.62 / 1.39
T [kN]	211 / 421 / 702	128 / 254 / 423
d [m]	0.19 / 0.37 / 0.62	0.31 / 0.62 / 1.04

Since the vertical frequencies shows low values a more detailed investigation is needed in future investigation. Equally, the horizontal frequencies for the long span lengths and large midpoint-sag are expected to come within a range demanding further analyses. That is, for slender pedestrian bridges the structural vibration will be an important design consideration. Pedestrian bridges with frequencies below 5Hz should always be controlled for possible excessive vibrations. Especially, with the first vertical in the range of 1.5-2Hz and the first horizontal around 1Hz. However, as indicated in Table 1, it may be possible initially to do a frequency tuning of the structure, which should be considered. For final design, always begin by consider the relations between plate thickness, mid-point sag, span length and possibly added mass, all from a serviceability point of view, then do ultimate design. It is in this range strongly suggested to use a pedestrian interaction model, which allows for a more accurate consideration of any feedback effects.

Basically, most of the common steels for structural applications could be used for the Rollout Bridge. Both hot- and cold-rolled plates may be shaped and delivered in sufficient lengths, hot-rolled likely being most relevant due to the minimum useful thickness of plate likely being about 10mm. In order to reduce bends and imperfections in the finished because of the rolling and unrolling process, a steel with a material curve (stress-strain) with a stable and continuous hardening behavior might be beneficial.

Reference

[1] TORROJA E. and POLIVKA J.J., *Philosophy of structures*, University of California Press, 1958, pp. 280.