A structural system for bridge design

The structural system presented here was created in Vienna 1995 by Dejan Erdevicki (M). He describes the main elements of the special girder design and some applications

Fig 1.

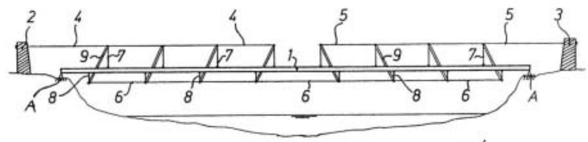


Fig 2.

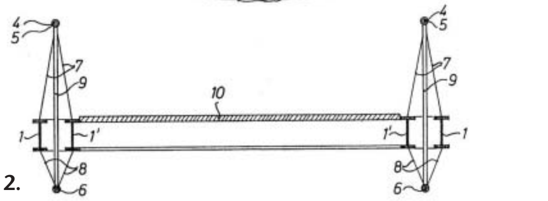
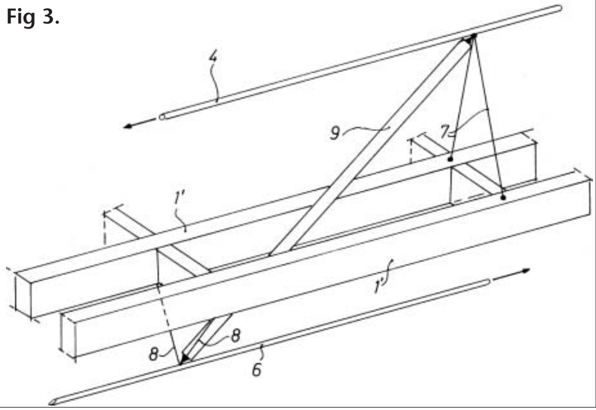


Fig 3.



The Erdevicki Structural System (ESS) consists of a main single-span girder element, top and bottom tension chords, diagonal compression struts and vertical tension elements connecting the diagonals to the girder. The top tension chord is anchored at its ends and the diagonal struts do not touch the girder. The system can be stressed to maintain tension in the top and bottom chords under all load conditions.

The basic system was patented in Austria as a 'special girder' under the number AT404482B (See Basic patented system in Figs 1, 2 and 3). It consisted of chords parallel with the girder, as shown on SL1. However, the chords do not have to be parallel and various modifications are possible.

The Singapore bridge example described in this text is a modified system where the tension chords are sloped towards the centre of the bridge. Another possible system modification, less structurally efficient but with a more desirable architectural appearance, is shown on SL2. For longer spans and shorter of diagonal elements, a possible modification is shown on SL3.

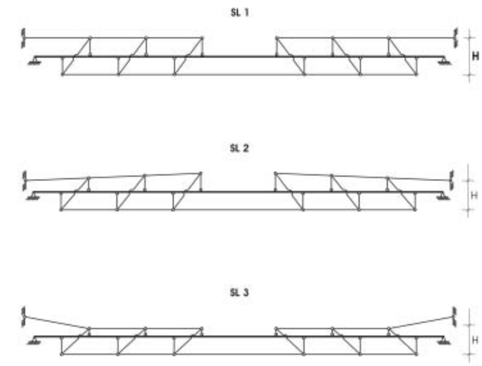
The number of diagonal bars can be chosen as desired by the designer but a minimum number of six is suggested. A larger number of diagonals would reduce the main girder dimensions and theoretically, it could be possible to design extremely slender girder loaded mainly with shear forces and virtually zero moment.

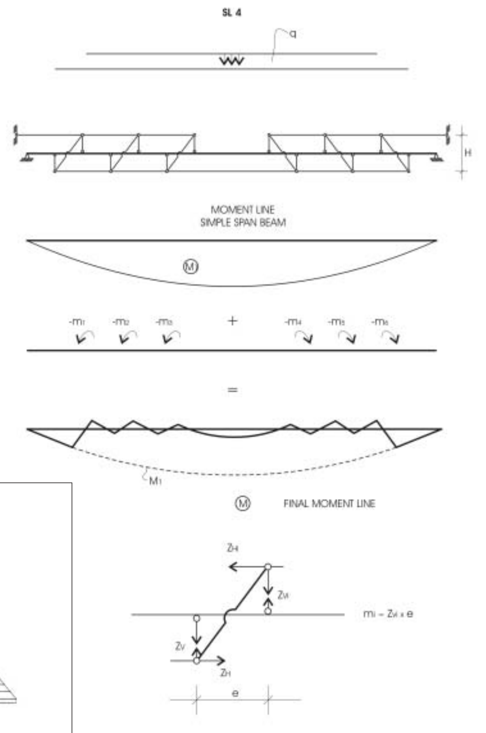
The basic system structural approach is to reduce the main girder positive moments by inducing negative moments along the girder length while not effecting the girder axial forces. The negative moments are created by a system of vertical tension rods as a pair of vertical forces in every strut area as shown on SL4.

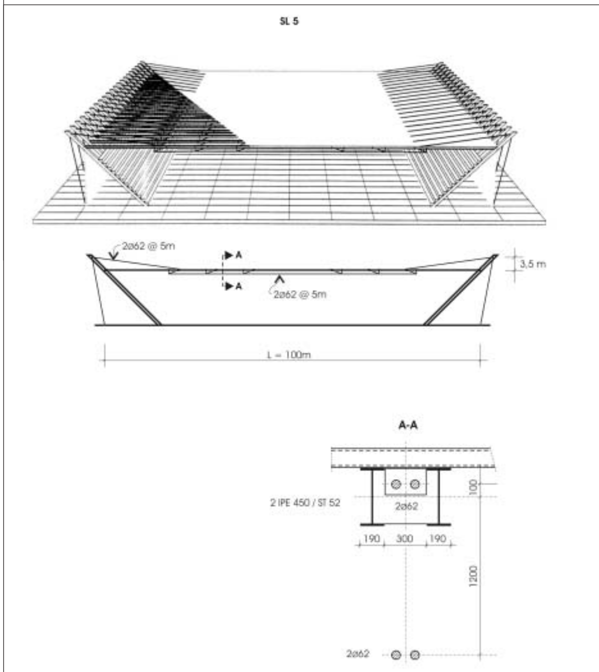
Through the system of diagonals and upper and lower tension chords, the negative moments split into two horizontal forces that are transfer to the anchor points.

Using the above-described system, it is possible to reduce girder moments to virtually any level desired by the designers. Girder dimensions are then determined by the capacity requirements for the bending moments and corresponding shear forces.

The relative short distance between the joints of the tension chords enable economical application of tension rods, very good vibration characteristics of the rods or cables as well as good utilisation of tension capacity from the applied elements.



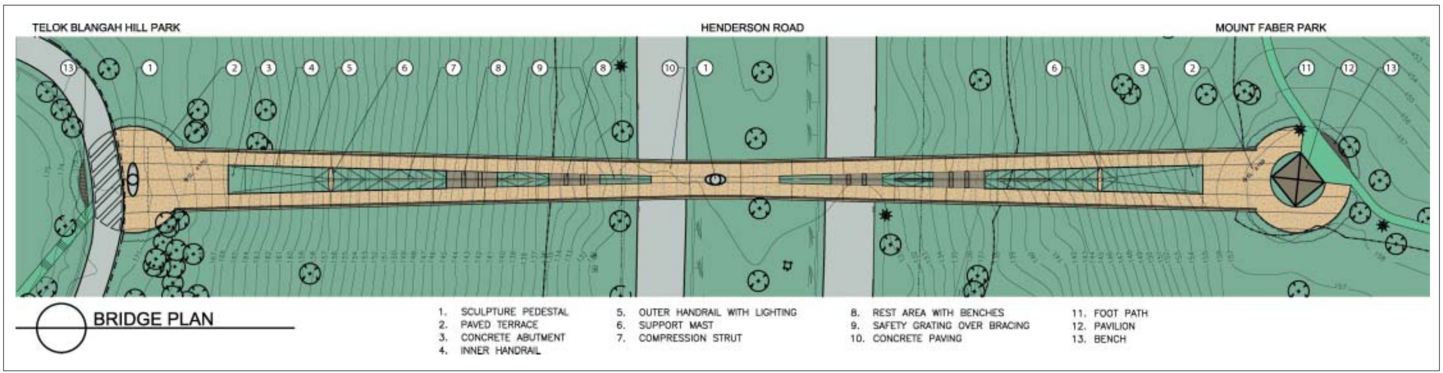




The main girder and diagonals can be designed in steel, concrete or timber.

Applications

The system described is applicable for pedestrian and highway bridges, as well as long-span roof structures. It would be most economical for bridges with rock abutments, where anchorage of the tension elements can be done in a simple and reliable way. The system would also be applicable to roofs with spans longer then 40m, such as stadia and sporting halls, aeroplane hangars, long-span industrial halls and similar



structures.

SL5 shows an example of a 100m span roof structure designed for the loading requirements of the City of Vienna and a maximal deflection limit on L/300.

Example: Pedestrian bridge

The preliminary design for the Henderson Crossing, submitted for Southern Ridges Bridge Design Competition in Singapore in 2004 uses a modified ESS where the main girder is a continuous beam and the tension chords are not parallel with the girder.

The design team members were:
Structural design: Dejan Erdevicki, Erdevicki Structural Engineering , Vancouver, Canada
Architectural design: Allan A. Hepburn, The Colborne Architectural Group Pacific Inc., Vancouver, Canada
Arup Singapore PTE, Singapore
Seifert Asia, Singapore

General design concepts

The proposed design of the Henderson Crossing Bridge provides a direct visual and physical connection between the pavilions on top of Mount Faber Park and Telok Blangah Hill Park. These two points generate its orientation in plan; the east end of the bridge commences at a circular terrace embracing the pavilion at Mount Faber Park, with the bridge sloping gently upwards to reach a similar terrace at the access road just below the Telok Blangah Hill pavilion. The bridge does not span the upper access road as this would create an uncomfortably steep slope along its length.

The general design intent is to create a span that is light, graceful and expressive. The two walkways sweep together in a gentle arc to meet in the middle, providing a larger midspan area overlooking the valley below. The supporting cables dive below the bridge deck at midspan, permitting a freestanding sculpture to be placed for visual focus at the centre.

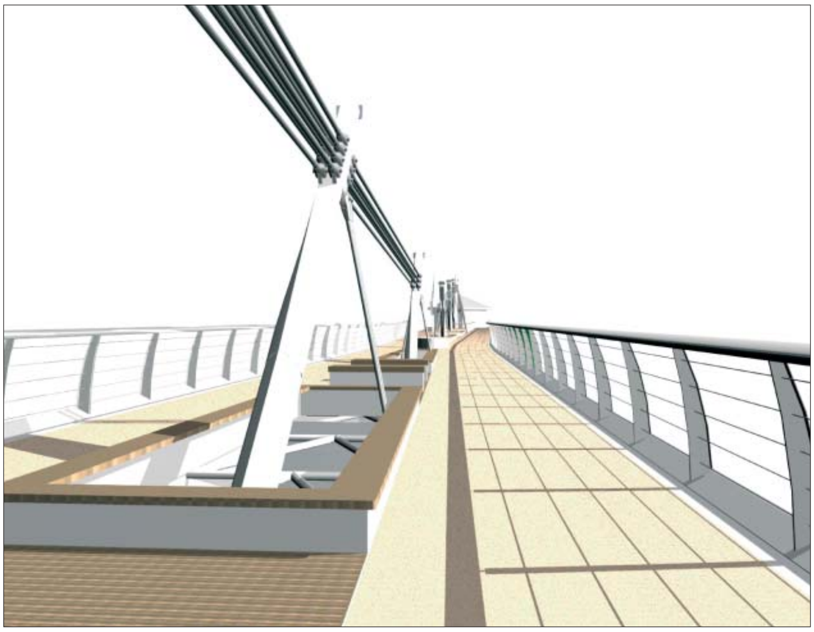
The bridge structure is white epoxy-coated steel with a fine exposed aggregate walkway. The compression struts diving between the walkways are expressively-shaped, with integral connection plates at each end supporting clustered groups of tension rods that pass over, through and under the bridge deck. Handrails along the outside edge curve inwards for an added sense of security. Intermittent crossing points between the two sloping walkways provide horizontal landing zones with benches for resting wheelchairs and prams and to foster general conversation. These are finished in teakwood for contrast and comfort. There are also low seating edges around the central 'holes' in the deck with aluminium safety grating infilling the interior area over the connecting bracing.

Dynamic performance

The first vertical dynamic cyclic frequency is f = 0.99Hz, and maximum static deflection from single pedestrian loading is 0.2mm. The bridge acceleration from pedestrian loading is calculated to be a = 0.12m/s^2 which is significantly below the required design target value of 0.5m/s^2. The first lateral cyclic frequency is 1.27Hz, an acceptable safe value (out of the critical range of 0.5–1.2Hz). Therefore, the proposed bridge structural system appears to perform well dynamically,

Right: View from below

Right: View from deck



Perspective view of bridge

with no requirements for any additional damping systems.

Main girder system
The main girder is created as a pair of two composite box girders braced together as a torsionally stiff unit along the main span. In the central area of the bridge these girders are merged into one section. The concrete walking deck is 100mm thick and is shear-connected to the steel box section below. This concept was chosen to provide a horizontally-stiff structure and to eliminate dynamic problems in the lateral direction, as well as to avoid wind flutter effects. Another advantage of this configuration is to provide intermittent gaps in the middle of the bridge to accommodate diagonal struts and tension rods.

The girder depth to span ratio is 1/111. The entire system is post-tensioned so that deflection in the middle of the main span is zero under the dead load. Maximum live load deflection is 240mm, and vibration sensitivity in both vertical and lateral directions is low.

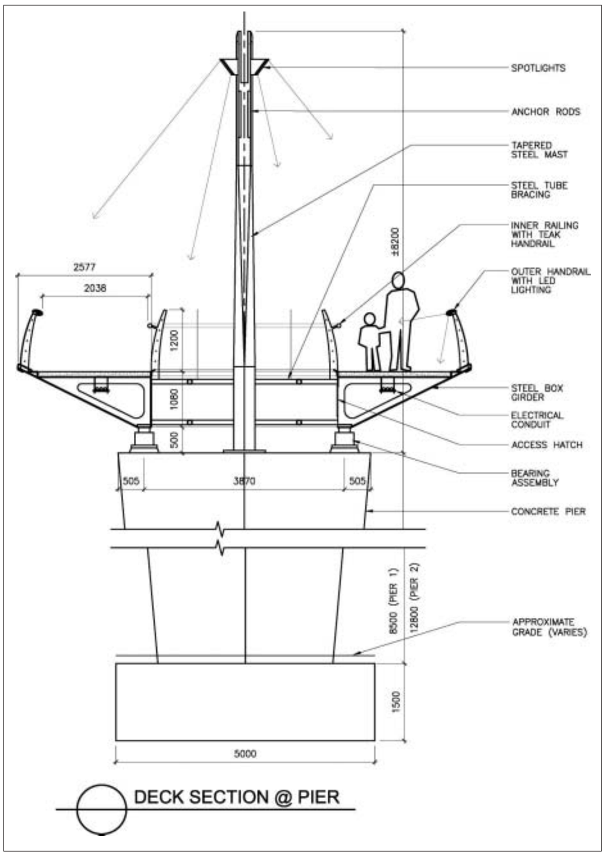
Tension rods
The proposed tension rods are a German system: PFEIFER Type 860 Rod System; 60mm diameter, with a yield strength of at least 460MPa. This system has left-hand and right-hand threads at either end of the fork connectors which enable exact adjustment of length by simply turning the rod. The rods are protected from corrosion by hot–dip galvanization that meet the design standard DIN EN ISO 1461. Rod couplers are only required below the central bridge span with a 40m rod length and for the bars connecting the pylons with the end abutments. Maximum calculated rod axial working load is 674kN, or approximately 83% of the bar tension capacity. A cable option was also considered, but the rod system was selected as it has obvious aesthetic advantages and has a lower cost.

Foundations, piers and abutments
Each of the reinforced concrete piers is supported by four 610mm diameter concrete-filled steel pipe piles; each pile cap is anchored with two soil anchors. Maximum working pile loading is calculated at 1300kN. Abutments are supported by six piles and anchored with 14 soil anchors to resist a maximum tension force of 6742kN. The proposed soil anchor system is Dywidag No.11 double corrosion protected steel thread bar anchors, grade 99/1030. Maximum anchor loading is calculated at 480kN.

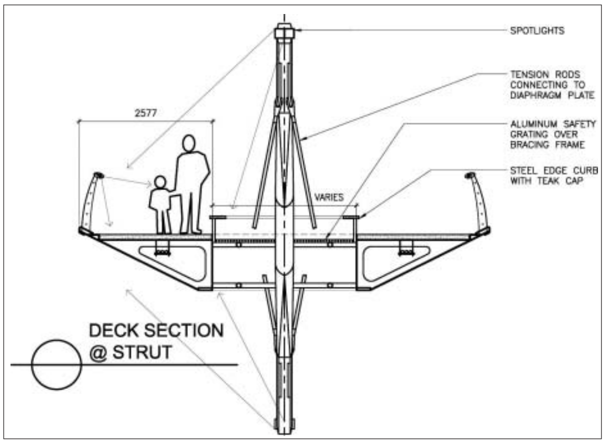
Conclusion
The described system gives designers a new opportunity to create long span structures. To date however, no structures have been built using this system.

This article was written to introduce the Erdevicki Structural System to the public and the engineering community and in that way, to contribute to the development of modern structural engineering. se

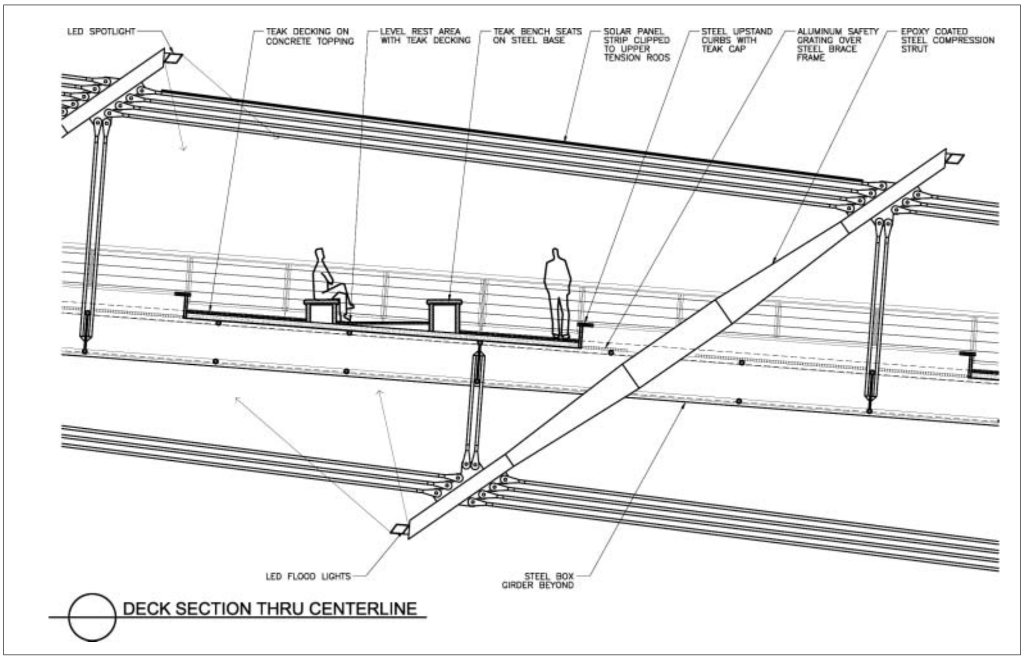
• Dejan Erdevicki can be contacted at: Erdevicki Structural Engineering, 300-4940 Canada Way, Burnaby, BC V5G 4M5, Canada (tel: ++ 604 293 1411; direct tel: ++ 604 880 1720; fax: ++ 604 291 6163; email: erdevicki@telus.net or erdevickid@ae.ca).



DECK SECTION @ PIER



DECK SECTION @ STRUT



DECK SECTION THRU CENTERLINE