EVALUTATION OF PRIMARY FACTORS

An evaluation of the existing Prince Edward Viaduct draws a clear picture of the issues to be considered in the building of a bridge over the Don Valley in place of the existing bridge.

HARD FACTORS

Functionality is the most important factor. The bridge is located in the near center of Toronto so it transports rush hour traffic daily. It must carry two subway lines (approx 8m below the road level), a total of five lanes of traffic (3.6 m wide) and two pedestrian sidewalks (3.0 m wide). The load must be supported over 468 m (384 m if abutments are kept).

Cost is an issue second in importance only to function. The bridge would be the effort of the metropolitan government, the city of Toronto. The area is close to Toronto's downtown. This means that a large population and much public attention are both present. A comfortable budget can be expected. This means that the bridge should be worth what its costs so as to make some profit in building it but not raise public outcry over a high budget.

Safety, due to a history of suicides, is a spotlight issue in this project. There is evidence that the convenience and, particularly, the grandeur of the existing bridge are responsible for the breaking point of the individuals. [1] Perhaps, a less edificial bridge would serve its mentally unstable travellers better.

Also in safety, recent safety checks by the TTC have revealed suggestions of structural failure of the bridge. This will have to be improved [2]. Thus, safety through design and aesthetics should be improved.

SOFT FACTORS

This bridge's social impact is largely imparted through aesthetics. The existing bridge is aesthetically proper for its time of construction but not for our day and age. It is symmetric. It has traditional arches. Both these elements are pleasing to the eye. But it is a web of metal. It seems to be the neatly soldered remnants of the scraps of the industrial age. It obstructs nearly a third of the valley below the roadway (the arch is nearly parabolic and the area of a concave parabola is a third of the area of a similar rectangle). The arches are in span-to-depth ratio (approx 1:1) that is well below Maillard's calculated efficient ratio of approximately 10:1 [3]. A lighter, less imposing bridge would serve the valley and the time much better than the existing edifice.

The environment has suffered in the current bridge's lifetime but not through the bridge's direct impact. [4] What a new bridge could do is to clear the valley of the metallic presence and create a more pleasant encapsulating view of the valley. Perhaps this tidier view would make people treasure the valley. This may indirectly lead to better care of the valley.

Culture, particularly the culture that leaves its mark in the near vicinity of the bridge (paths, walls etc., is influenced by many more factors than a bridge. But a good bridge may lay some positive impact on the area. Currently, much absurd graffiti, garbage and waste cover(s) the area surrounding the bridge. The bridge is old and anyone passing by can see that it is not a prestigious bridge. A well-made bridge would be prestigious and force the surrounding culture to give more respect to the area.

DESIGN PHILOSOPHY - In summary the bridge should:

1. support the existing live load (subway, pedestrians & roadway traffic)
2. a) obstruct as little of the valley as possible

   b) have the minimum cost required
3. posses elegance and prestige
4. have as few supports descending into the valley as possible

Because of these requirements I was searching for a bridge that would use the least amount of material possible for the job (points 2a) & b) support this). To me, this meant that the bridge would end vertically at the roadway; no suspension bridge, cable-stayed or overdone trussed bridge would be considered. Arched and box girder bridges were the only possibilities.

REFERENCE STRUCTURE I

The Kochertal Viaduct in Germany designed by Leondhart is a magnificent bridge [5]. It is simple, minimal and it seems to be separate from the valley because of its enormous height. This sort of bridge would be inexpensive to build because it is a box girder, possibly the most inexpensive design technique for long-span, dry-land construction [Fig 1]. The bridge would be simple to build using the sliding cantilever system. It could possibly use only one support beam covering the entire 384 m length (192 m/ span) with a depth of 8.4 m. This would be possible since a recommended ratio of box girder depth to span is 20 [7]. This bridge would have a ratio of 23, a suitable value.

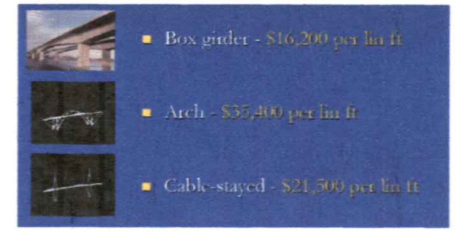

Fig. 1 [6]

REFERENCE STRUCTURE II

The Felsenau Bridge in Switzerland designed by Christian Menn [8] is a lesson in efficiency. It is a box girder arch. It has a ratio of span : depth at the center of 49:1 and a ratio of 17:1 at the supports [7]. This would be perfect for an 8.4 m depth at the middle providing a maximum span of 144 m. By dividing the bridge into three parts (two main supports), arches of 128 m each could be achieved. The bridge would be aesthetically mature and simple yet it would not obstruct the scenery too much.

The only problem is that the bridge looks too thick on the Don Valley. Because of the subway requirement, the depth of the bridge clearly took up a large fraction of the total vertical height of the bridge. The gracefulness of the arch was lost to the thickness of the box girder.

REFERENCE STRUCTURE III

An aesthetically daring bridge is the Sunniberg Bridge in Switzerland as designed by Christian Menn [8]. Though I was not considering cable-stayed bridges as a viable option, I liked that aesthetic impact of the bridge's pier 'risers'.

CRITICIZING THE REFERENCES

The three ideas varied in functionality and purpose. I had a functional bridge (Kochertal), an artistic bridge (Sunniberg) and a 'natural' bridge (Felsenau) to work with. The Felsenau Bridge is simple, graceful and elegant. It would be cheap to build but would add a modern touch to the Bloor street landscape. Its natural qualities fit with my initial requirements so I picked it as my main reference structure.

I also liked the simplicity of the Kochertal Viaduct and considered making a more daring span for my final bridge. I liked the monolithic connection of pier to box girder is used in the Sunniberg bridge. I wanted to develop the idea of two separate box girders supporting the separate subway tracks.

PRODUCING THE FINAL DESIGN

Span

The outer cantilevers of the original Felsenau rough drawing ended in with large moments close to the original abutments. This was a problem because there was no moment support provided at the abutments. I increased the length of the spans so as to create four semi spans instead of the previous six. This ended the arch at lowest depth (and lowest moment) at the abutments. This would greatly reduce any moment the abutments would have to take. No special abutments would have to be built.

Piers & Abutments

The piers had to be rotated so as to better resist cantilever moment produced by the large spans. Two piers acting in line and at a distance from each other would create a stronger resistance to moment than one support. Original abutments are kept if possible.

Box girder interior

The original box girder design was composed of a thick double layered box girder. A better design was to omit the inside box girder overlay and simply provide an area for a support beam for the subway tracks to be placed there periodically along the span of the bridge. This would more efficiently support the span-length subway tracks.

Box girder truss

This is the greatest innovation of the design. The bridge looked heavy. The solution would be to create more open space. A steel truss would break the simplicity of the bridge fabric. A better solution would be to make the box girder manufactured in a truss shape. The shape could be strengthened through pre-stressing the factory concrete. Off-site concrete functions much better than onsite concrete [7].

The shape of the truss could be quite open since any lateral load could be carried by the top and the bottom of the box girder. The femur, from the human body is able to resist much compression; so too can the egg. These two structures were traced to provide a guideline for the truss design. It was made sure that the struts still functioned as trusses; a line could be drawn between top and bottom opposite corners.

CONCLUDING

Overall, the design proves to meet all criteria. It uses a proven technology, the box girder to safely support the load; it has functionality. It has a minimum physical presence in the valley and looks light because the concrete monolith is broken apart by the truss system; it is aesthetically and socially fitting. It uses the cheapest of construction forms, the box girder; it is cost effective. It is based on a design that is recognized world-wide as the work of a master designer, Menn; it would doubtlessly be an elegant addition to the area. Environmentally, it would preserve the valley as best as possible with the minimum practical number of piers in the valley bottom. The bridge would work simply, cheaply and elegantly.

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[4] A. Bagrianskaia. *Rivers and the Urban Environment: The Don River Story.* Thesis, Div. Civil Environment, Humber College, 1999.

[5] F. Gottemoeller. *Bridgescape: The Art of Designing Bridges.* New Jersey; John Wiley & Sons Inc., 2004.

[6] W. J. Bohlen, Preliminary Design Concepts for the Ballard Bridge. Federal Way.

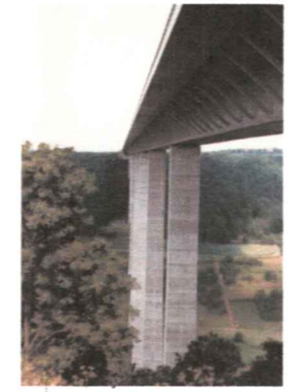
[7] P. Gauvreau. *Personal Ineterview.* November 21 – 30, 2005. Email: pg@ecf.utoronto.ca.

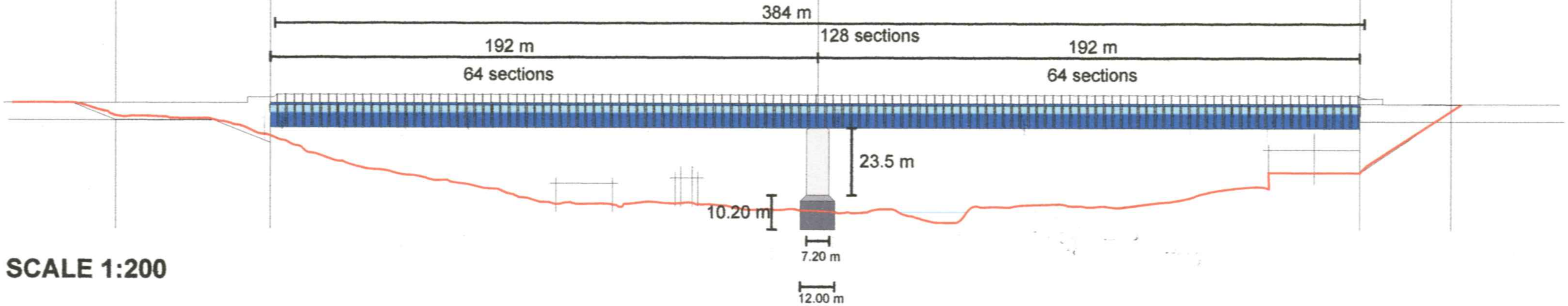
[8] F. Gottemoeller. *Bridgescape: The Art of Designing Bridges.* New Jersey; John Wiley & Sons Inc., 2004.

CONCEPTUAL ROUGH DRAWING 1

SCALE 1:2000

Reference: Kochertal Viaduct, Gieslen, Germany
FRITZ LEONHARDT, 1979
[G4]





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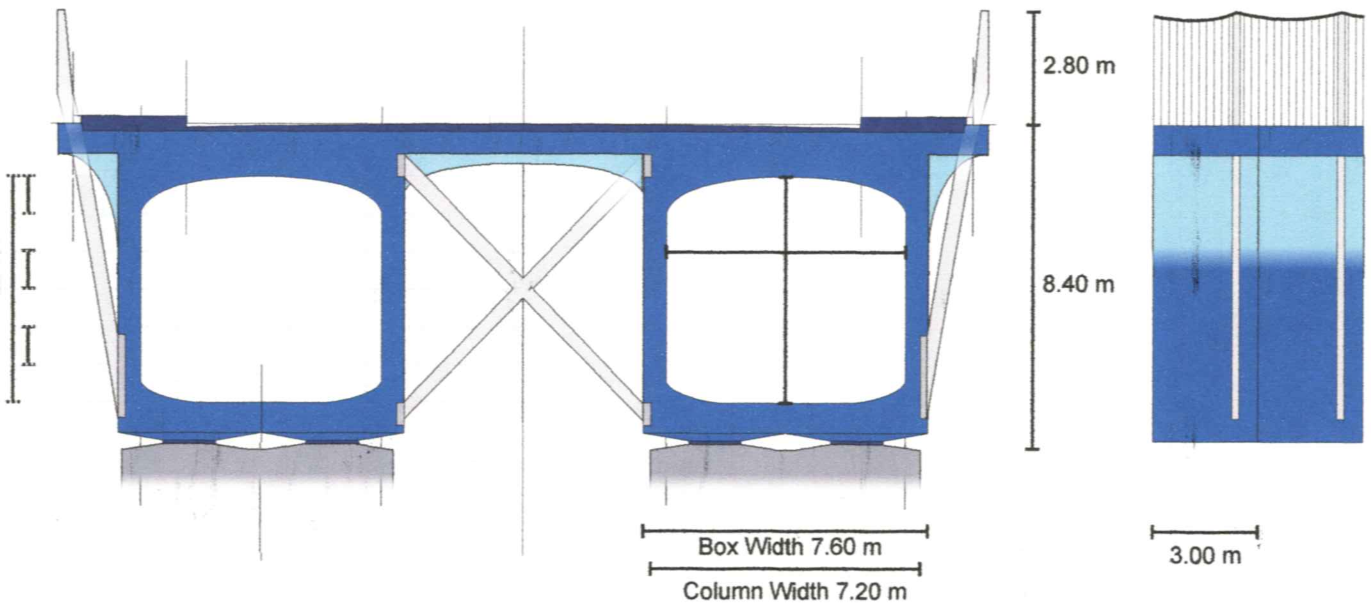
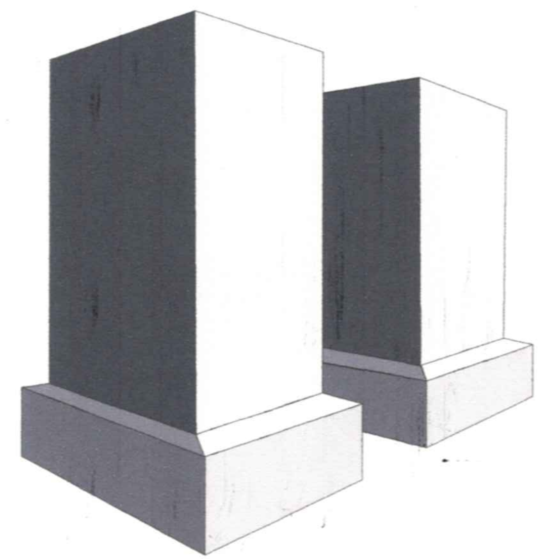
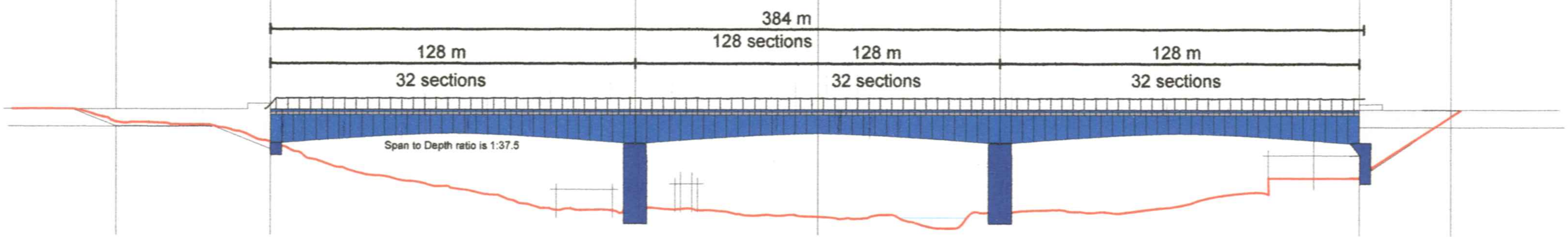


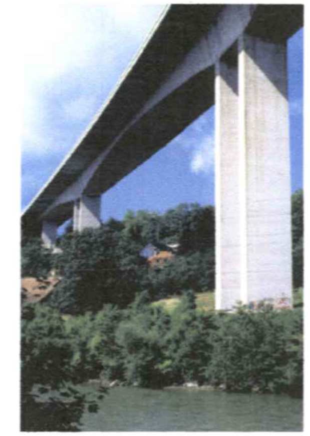


CONCEPTUAL ROUGH DRAWING 2

SCALE 1:2000

Inspired by: Felsenau Bridge, Aare River, Switzerland
CHRISTIAN MENN, 1974
[G2]





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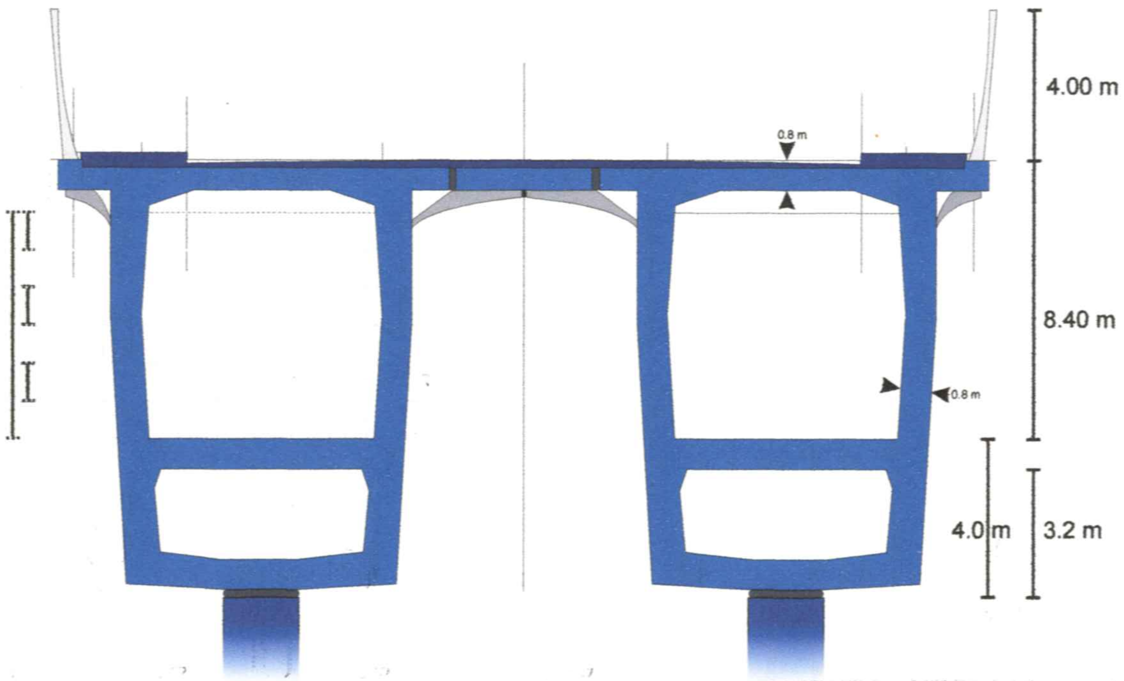
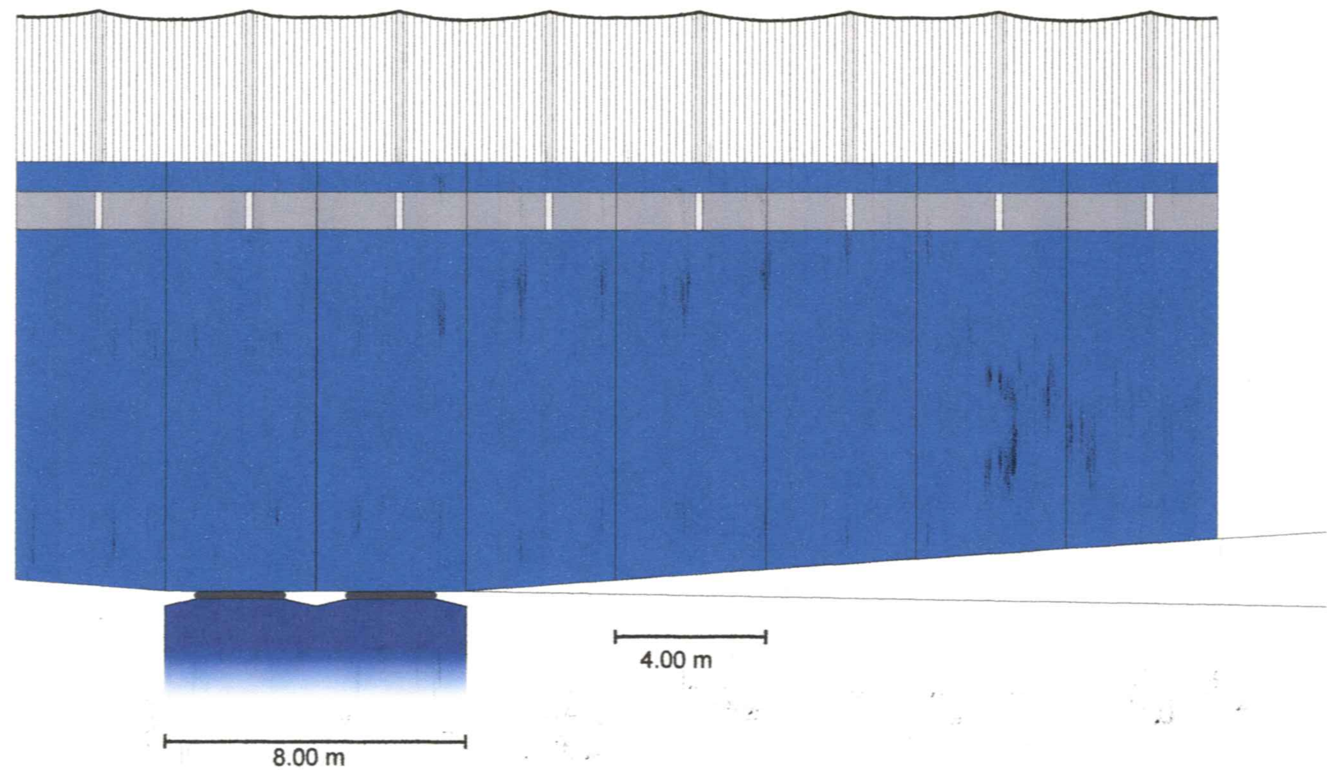




University of Toronto ESC 101F Engineering Science Praxis

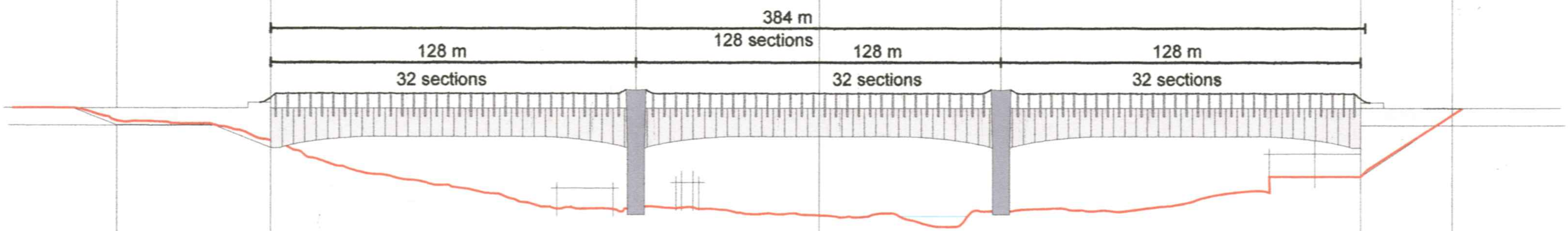
PRAXIS DESIGN III

Serguei Bagrianski Tues 3004 Dec 2, 2005

CONCEPTUAL ROUGH DRAWING 3

SCALE 1:2000

Reference Sunniberg Bridge
CHRISTIAN MENN, 1974
[G2]



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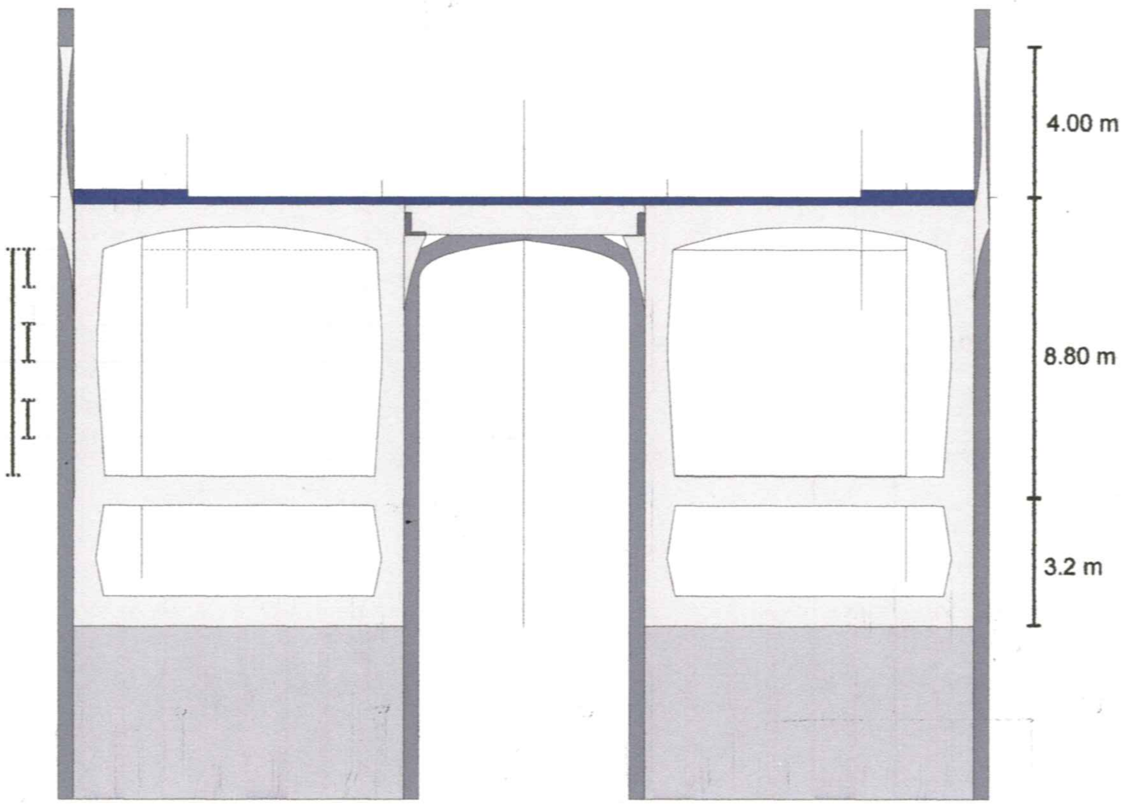
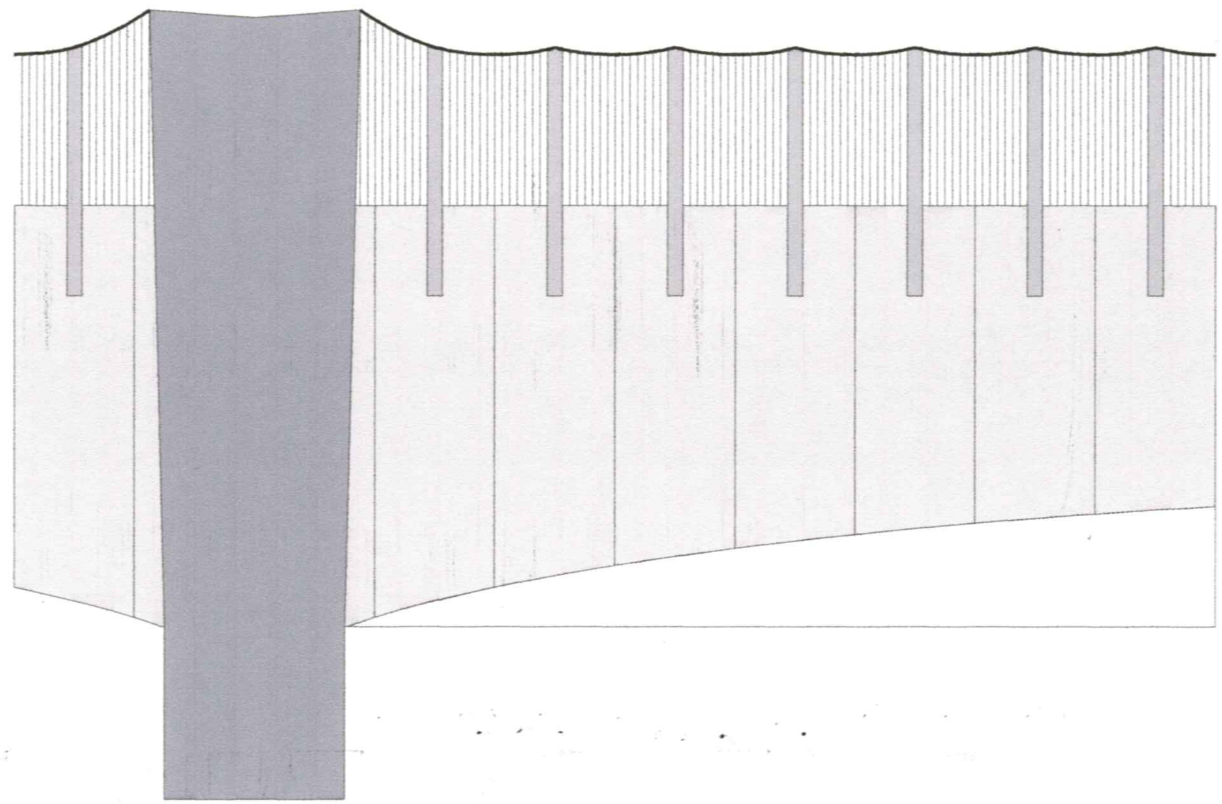
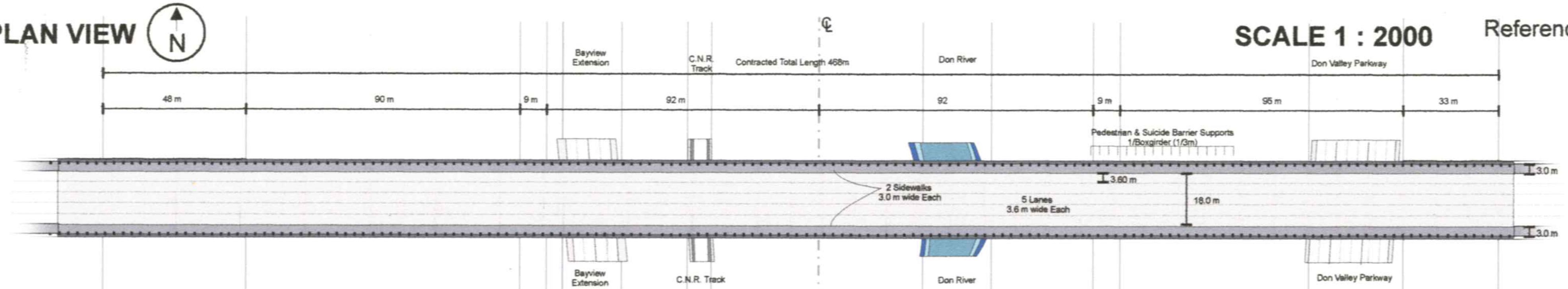


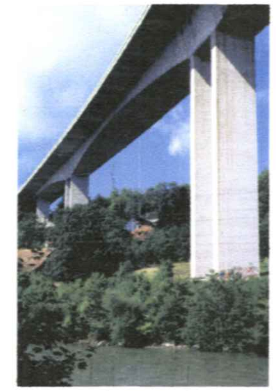


PLAN VIEW

SCALE 1 : 2000

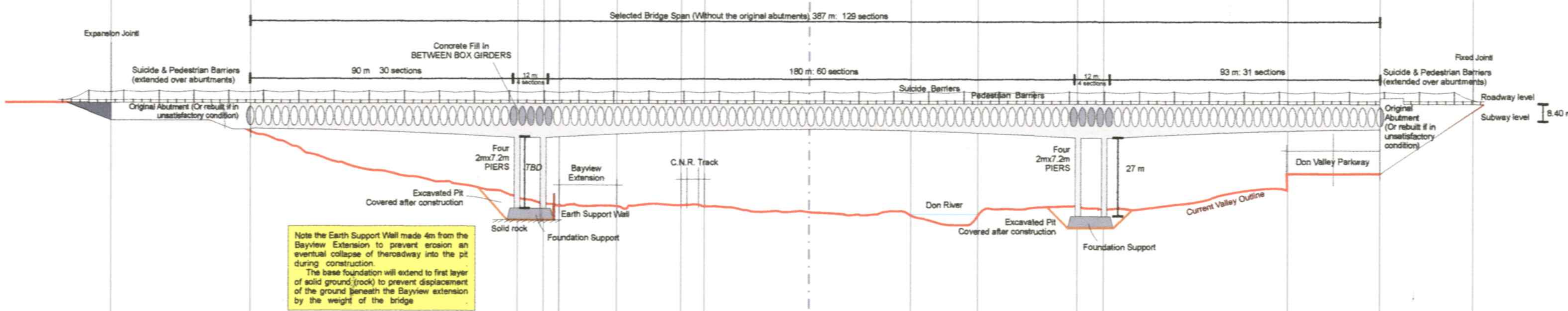
Reference: Felsenau Bridge, Aare River, Switzerland
CHRISTIAN MENN, 1974
[G2]



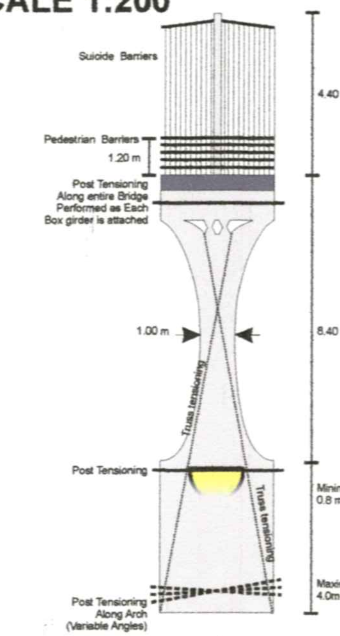


ELEVATION VIEW

SCALE 1 : 2000

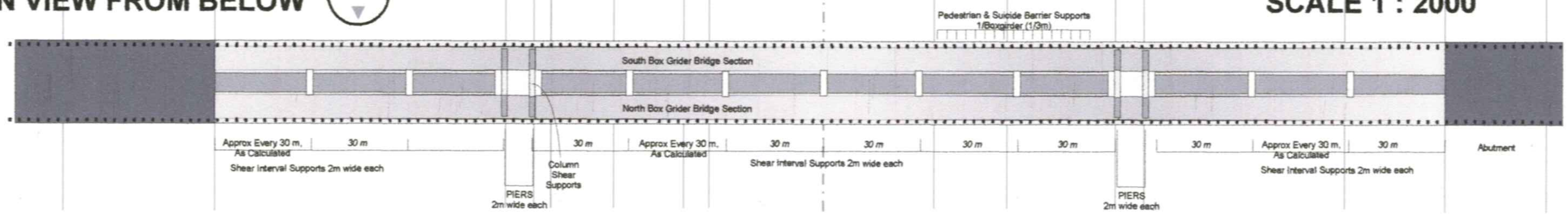


INDIVIDUAL BOX GIRDER SCALE 1:200



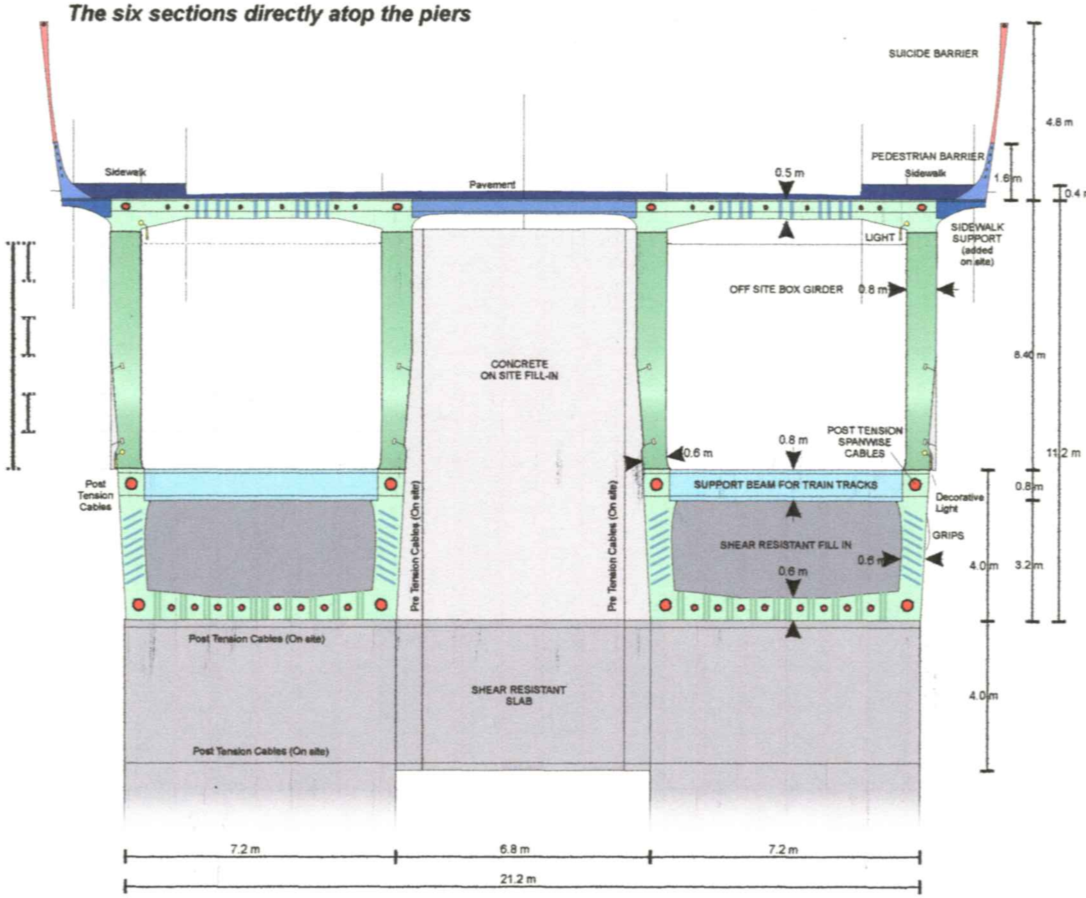
PLAN VIEW FROM BELOW

SCALE 1 : 2000

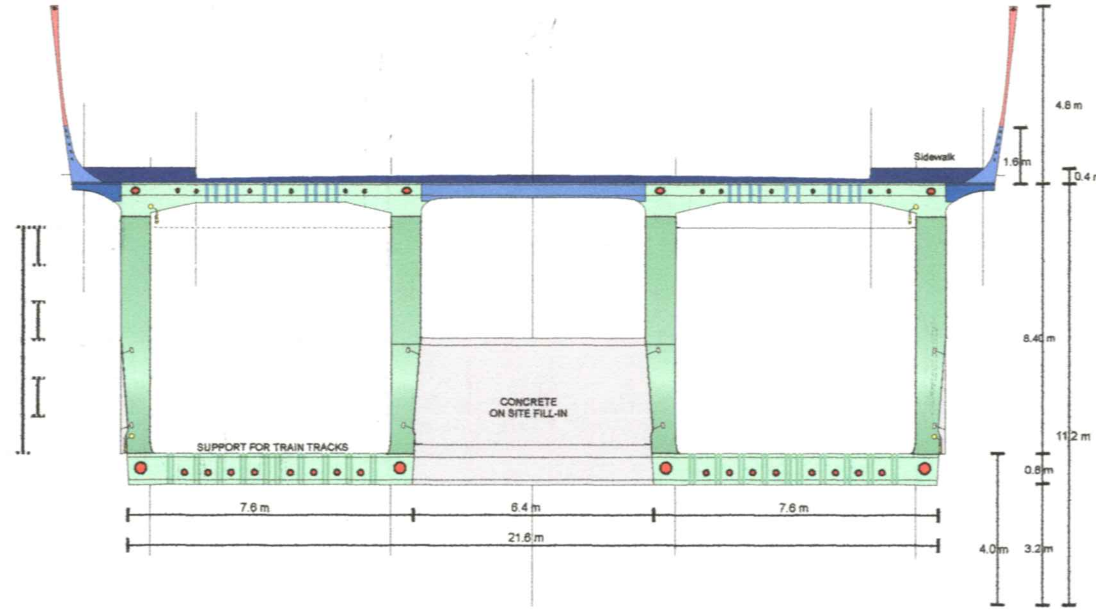


CROSS SECTION AT PIERS — SCALE 1 : 200

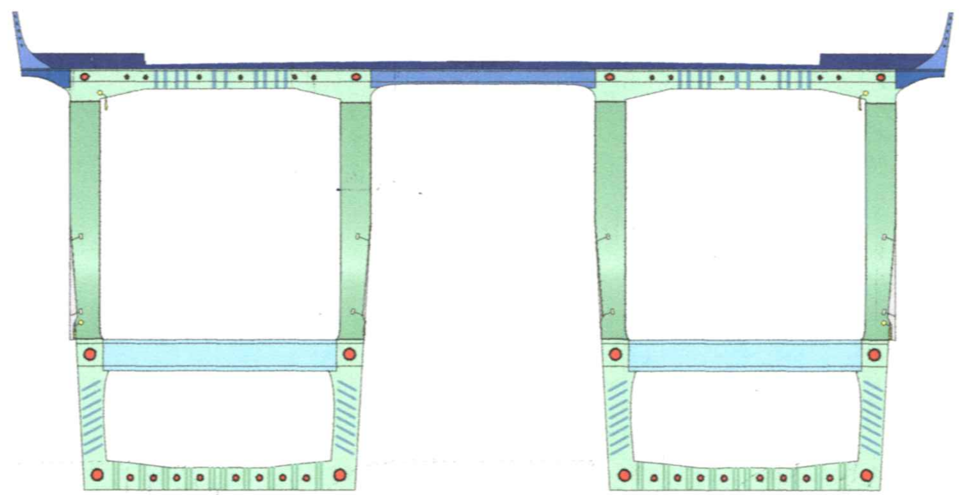
The six sections directly atop the piers



CROSS SECTION AT MIDSPAN — SCALE 1 : 200

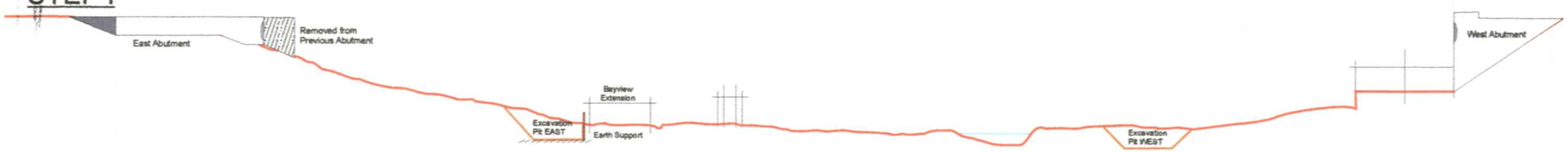


TYPICAL CROSS SECTION WITHOUT SHEAR SUPPORT — SCALE 1 : 200

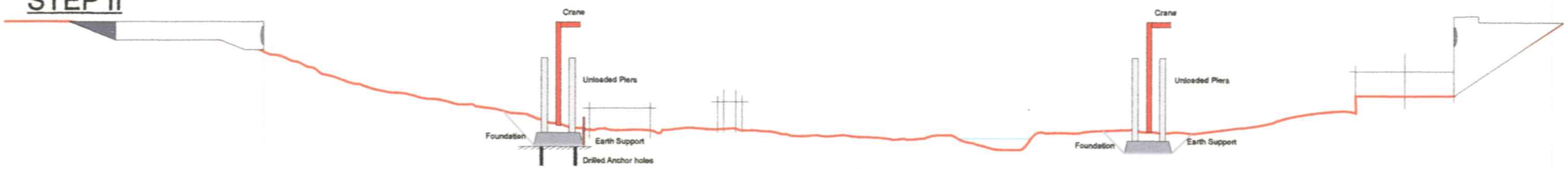


CONSTRUCTION

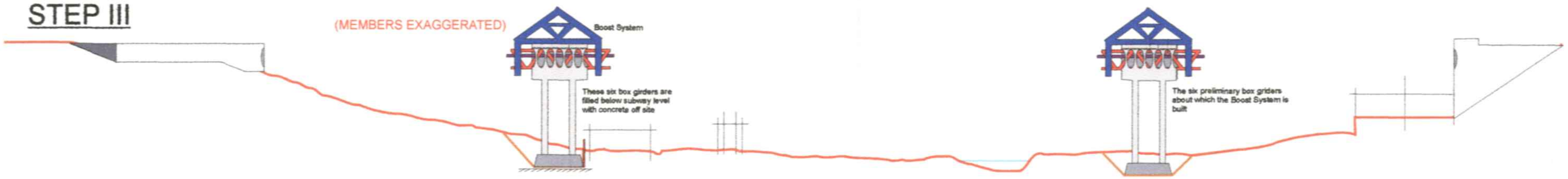
STEP I



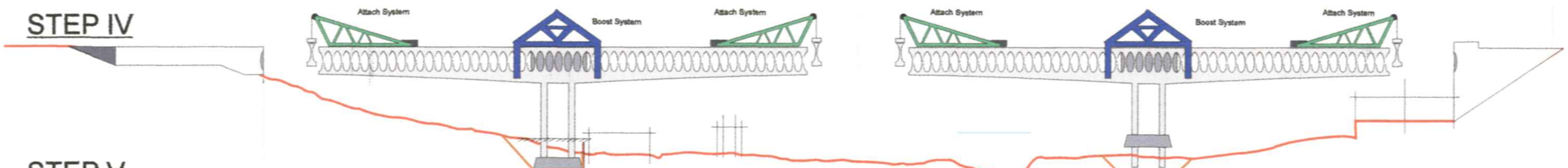
STEP II



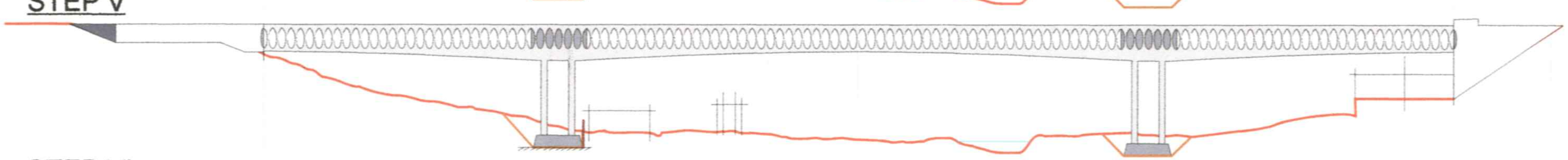
STEP III



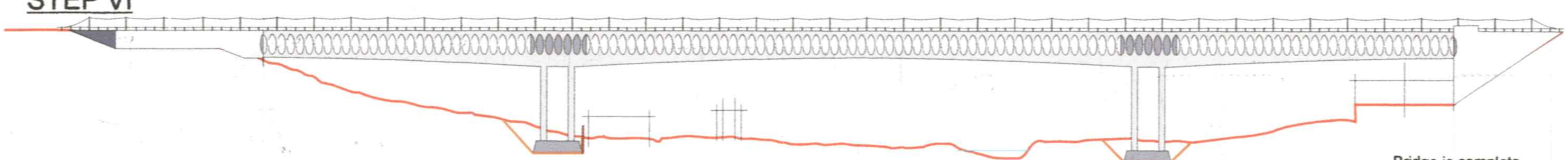
STEP IV



STEP V



STEP VI



I) EXCAVATION, SUPPORT & ABUTMENTS

- West Pit is excavated to a level at least 10m below lowest ground level. The East pit is dug to the first layer of solid rock. Earth support is provided on the side adjacent to the Bayview Extension to prevent onsite soil erosion and crumbling of the roadway into the pit.
- Abutments are inspected. If they are in satisfactory condition, the West abutment is kept as is and the East abutment is shortened to accommodate bridge span (to marked spot). If they are in unsafe condition, the abutments are either repaired or reconstructed. The bridge motifs (0-shapes) are inscribed into the abutments.

II) FOUNDATIONS, PIERS

- Foundations are built. Pretensioned onsite concrete is used. Holes are drilled into the rock of the East pit and the foundation is anchored in place. Once the base layer of foundation is in place, the prestressed Piers (transported in box grider-like segments) are put in place and post-tensioned. A simple commercial crane is used. It is placed at the center of the foundation and lifts all the pier segments..
- Once piers are slightly over ground level, the excavation area is filled to provide for the large moment the structure will face in further construction.

III) CANTILEVER, BOOST SYSTEM

- The crane is used to lift six box girders (for every piers [24 box girders in total])
- Then the crane is used to lift the Boost System (One for West and another for the East). This is a light fink truss machine (blue) that can support the weight of at most four box girders at a time. It works by lifting up a box girder through the 6.0 m wide gap between the two bridge segments (North and South sides). The individual box girders are then carried by a conveyor belt (purple) supported by trusses (blue) to the edge of the cantilever. Two box girders can be attached at once (from both ends simultaneously). This system is mostly for BOOSTING the box girders. Another system, the placement system is used to hold the box girders in place until they are secured at the ends of the double cantilever.

IV) CANTILEVER, ATTACH SYSTEM

- The Boost system lifts each box girder to road level. The sections are then transported (by a machine of choice) to the end of the cantilever. The Attach system (Green) can be used for carrying the girders but it is mostly used for attaching the individual box girders sequentially, The Attach system is used in four locations. These machines are simple trusses that can be lifted into place by the Boost system.

V) CONNECTION ACHIEVED

- The connection between the middle box girders is reached as are the connections between abutment and box girder.
- The bridge is post-tensioned along the entire length; along the arch, the bridge top, and the subway level bottom.
- After a safety check, the Boost and Attach systems are removed.
-Structurally, the bridge is nearly complete.

VI) BARRIERS, ROAD CONNECTION, SUBWAY TRACK LAYOUT

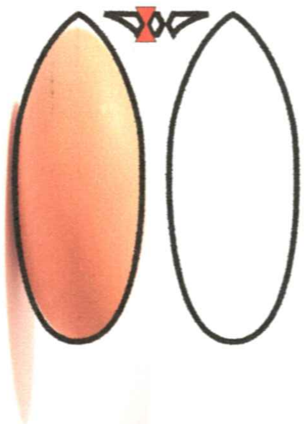
-The gap between the North and West bridge sections is closed by placing a precast concrete slab (one per box girder) into place and post tensioning in the cross sectional plain at the road level.
-The suicide barrier wings and pedestrian barrier wings are attached by post tensioning again through the road level plain.
-The entire road level is post tensioned.
-Subway sections are laid into place: Cross-sectional piece are placed at intervals at the end of every box girder; I beams are placed along the length of the bridge; The subway track's short members are placed onto the I beams and then the track itself. All is fastened by bolting.
-Cables are strung for the suicide barriers; rods for the pedestrian bridge are put into place; the barrier is extended into the abutments.

TRUSS DESIGN IDEA SYNOPSIS

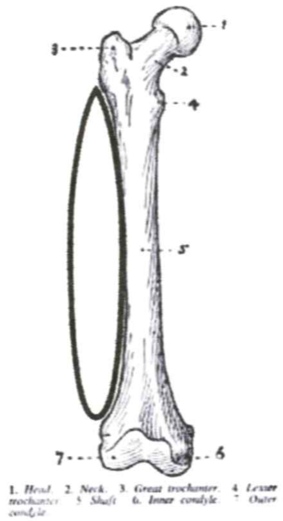
VESSY BRIDGE [G2]
Robert Maillart

Concrete truss idea from Chandoline Bridge.
Shape of main arch from combination of egg and femur.
Upper minor truss work from Vessy Bridge.

CHANDOLINE BRIDGE [G2]
Christian Menn



EGG [G3]



FEMUR [G1]

GRAPHIC REFERENCES

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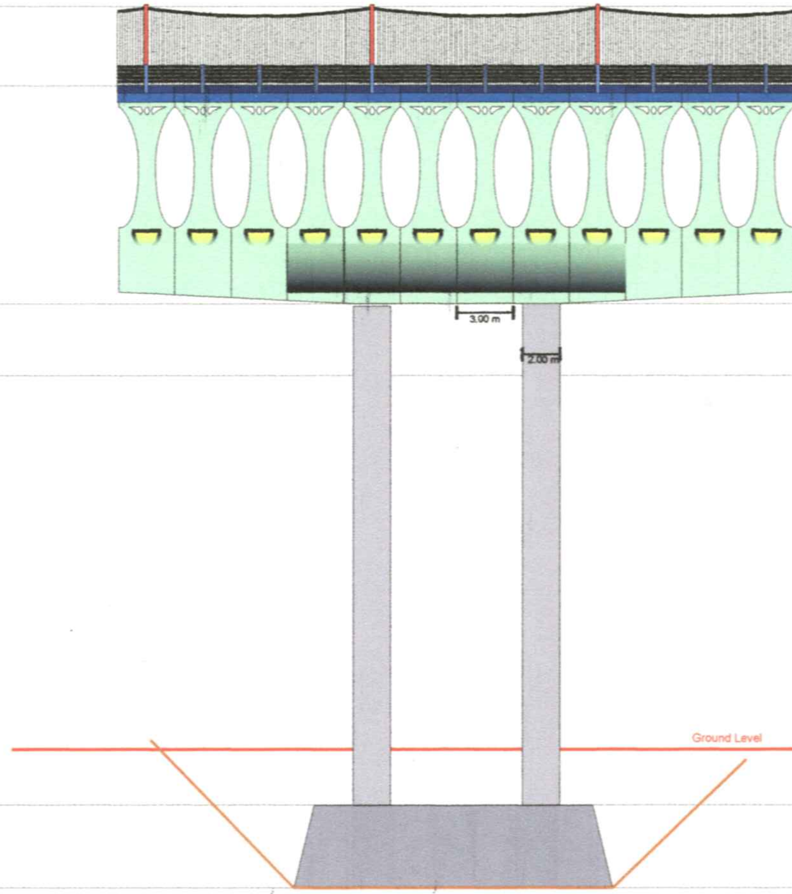
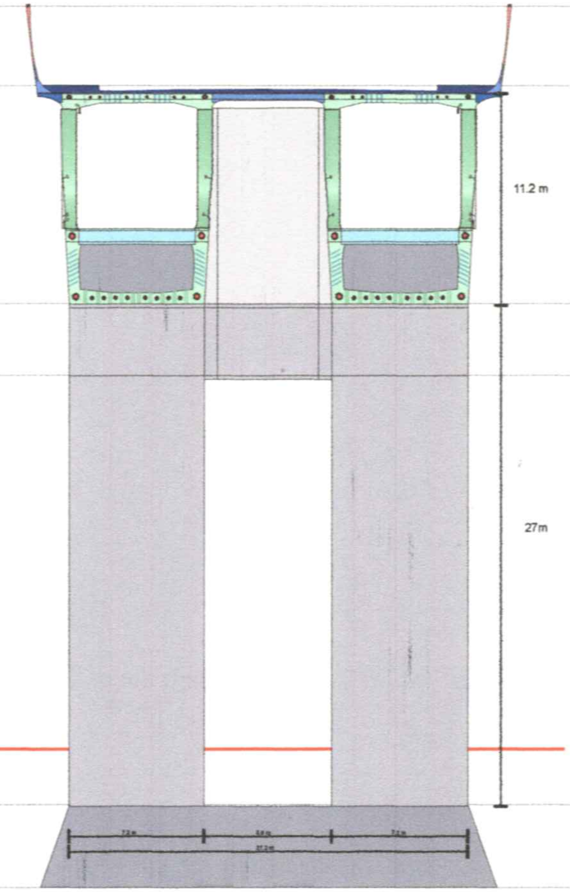
EAST PIER AND EXCAVATION AREA

BOX GIRDER ELEVATION VIEW



SCALE 1 : 400

FULL X-SECTION



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