History and Aesthetics in Suspension Bridges
Today we trace the evolution of steel bridge design from its first American innovator, JA Roebling up through 1930’s New York

In the 30’s in New York, despite hard economic times, many huge structures were erected
The Empire State Building, tallest in the world

About which more later
The GW Bridge, longest suspension span by a factor of two, and
The Bayonne Bridge, longest arch span in the world, barely surpassing the Sydney Harbor Bridge
These last two were both designed by Othmar H. Ammann, the greatest bridge artist to use steel as his material.

Ammann was born in Bern, graduated 1902 from ETH and 1904 to USA. Worked from 1912-23 for Lindenthal.

He would study under Karl Ritter protégé of Carl Cullmann.

The Swiss were uniquely able to mediate the scientific rigor of the Germans with the design elegance of the French.
The story of Ammann and the GWB begins with Gustav Lindenthal, the dean of American bridge engineers.

Ammann had cut his teeth as design assistant to Gustav Lindenthal at the Hellgate Bridge.

The last great bridge of the railroad bridges. From here on the great bridges would carry road traffic rather than trains.

Here we see two bridges, Hellgate and Triborough, on which Ammann would work, but not express his aesthetic vision.
Hellgate designer Lindenthal
Born in Brunn in Austria, now Brno in the Czech Republic
Designed a bridge at Pittsburgh, a lenticular truss to replace Roebling’s Smithfield St. Bridge

He was a great player with form, and in fact employed both Ammann and Steinman at various points

Lindenthal did not reach the apex of structural art, but he was so conscious and insistent about the aesthetics of his work, and about its symbolic effect, that his proteges, Ammann and Steinman, had no choice but to think about these issues.

He had his own firm at Pitt and would become obsessed
Hellgate under construction

Completed 1916 977 feet
Preferred the spandrel braced form to the crescent form, 
german vs. french

Carl Condit said that Lindenthal had valued dignity over 
elegance

Hellgate is an example of the influence of architecture on 
structural design where useless masonry towers were added 
for visual appeal.

They mask the reverse curvature of the arch which is an 
odd, perhaps irrational structural feature

The upper chord carried very little load and ends in mid air 
so that it must be force free at this location

The lower chord does the work, ending in a hinge which is 
not expressed structurally.

This contrasts with Eiffel’s designs in which the hinge is 
expressed by a narrowing of the arch form
Ammann was influenced by Lindenthal and designed non-structural masonry abutments for Bayonne.

He was lucky that finances dictated the omission of the masonry.
But the tangle of steel at the supports attests to the incorrectness of this notion. The masonry was not added because of depression era economic constraints.

70% longer than Hellgate with less than ½ the steel per foot(?)

Does exhibit significant lightness, though it perhaps does not rise to the level of Garabit.

Opened 1931 1675 feet, 2 feet longer than sydney.
One can however, sympathize with the desires of Lindenthal to improve aesthetics through architecture, as, following Roeblings triumph at Brooklyn subsequent bridges had aesthetic deficiencies.
Williamsburg is simply ugly. With the very deep stiffening truss and complex metal towers, showing a lack of talent on the part of its designer Leffert Lefferts Buck.

Back stays not structural

Towers are awkward

The walkway is just a horrible place to be

40’ deep truss 1600 feet long opened 1903
Manhattan bridge is an improvement over Williamsburg, but still the towers look to me like a masonry form in steel

1909 opening 1470 feet span

Moisseiff designer
At Bear Mountain (Howard Baird) and
Not offensive, but not striking
1632 feet opened 1924
Florianopolis we see clearly that efficiency and economy do not lead inexorably to elegance.

This is really strange and appears to be a composite of different bridge forms, perhaps even done by different designers.

This is offensive.

This bridge is in Brazil by the Steinman firm.

1114 feet opens 1926.
When Amman began working on GWB, the longest bridge in the world was in Philadelphia across the Delaware, the Ben Franklin Bridge.

Heavy masonry over the anchorages.

Designed Steinman.

1750 feet opened 1926.
For the Hudson River crossing many different spans had been proposed at various locations, including one by Lindenthal’s in 1888

We need to replace a ferry crossing just as at Brookyn
Sometimes (top) we can see the result of design by committee instead of by a luminary individual.
Others show redundant or unclear structural systems such as that combining an arch and suspension system

Lindenthal, at top, tried to get the biggest bridge ever built constructed, 12 train tracks and highways.
Amman was dissatisfied with the gargantuan proportions of this proposal,
Absolutely massive! 10 RR tracks on one deck, 16 lanes of traffic and four subway tracks on the other

Lindenthal’s allegiance to the RR killed him here (social)

Note stiffening in the cables
departed the Lindenthal firm, and, more or less in secret,
Began his own work on a Hudson River span which would be more suitable for automobile traffic.

He proposed moving North to get a shorter span and better approaches.

Note that here we have plain metal towers.
Ammann added the masonry as a nod to the Brooklyn Bridge and the older British forms which he so admired.
GWB masonry covering

Designed by Cass Gilbert

Ammann felt he needed architectural assistance to get the towers right

Gilbert had designed the Woolworth building
He was hired by the Port Authority to do the bridge, and came up with this.

He changed his design of the towers to have a masonry covering of reinforced concrete and granite, aided in this design by Cass Gilbert.

The masonry was never added due to financial constraints.

The bridge was originally built with only one deck, and virtually no vertical stiffness.

This lack of stiffness was a result of his reliance on the deflection theory of Moisseiff and Melan.

He seemed to not recognize the earlier series of suspension bridge failures, though this is open to debate.

We can contrast this with B Baker’s approach at Forth, where he perhaps overcompensated for the experience at Tay.
The success at Washington Heights led to a trend towards extremely thin decks as at San Francisco

Moisseiff was called in to consult here, and went with a thin thin deck, spurred by defelction theory

He also designed the Manhattan Bridge
6-26 bear mountain bridge_150dpi.jpg

Which contrasts with the very deep stiffening truss at Bear Mountain

Note this preceded GWB
Steinman at Deer Island pushed the envelope as far as it would go.

Here he specified a plate girder stiffening system rather than an open truss system, which would presage aerodynamic problems.

Diagonals are a retrofit.

Ammann and Steinman competed as Stephenson and Brunel, but were far from friends.

Steinman was born in NY 1882, went to City College, and taught at Idaho and CCNY first US educated in the course.
Amman also used a plate girder at the Bronx-Whitestone bridge over the East River estuary. He predicted, correctly, that this would set a precedent, and it did, tragically.

Note also the cleaner lines of the towers than at GW, forerunner to Verrazano.

1939 2300 feet main span
The plate girder form was also used at Tacoma by Leon Moisseiff, resulting in disaster.

2800’ by 8’

Moisseiff was Ammann’s consultant on the GW span.

Note very tall narrow towers
This structure, galloping Gertie, was destroyed by wind less than one year after completion
Torsional oscillations
Insert movie here
The bridge was rebuilt of the same form, but with a radically stiffer deck system.
The collapse of the bridge stimulated a retrospective look at previous bridge collapses such as that at Menai.
And that of the Brighton Chain Pier
Forensic investigation of the Brighton disaster
Indeed the very narrow profile of Tacoma, coupled with its solidity, combined to create aerodynamic effect leading to its failure
Its failure. Note here that no one died, excepting a small dog. People had been coming to “ride” the bridge prior to the disaster.
6-36 new tacoma narrows bridge_150dpi.jpg

Very deep girder at new Tacoma
Many bridges which followed the GW had similar problems with wind, especially two which used plate girders to stiffen the decks.

Deer Isle

The towers are the absolute signature of Stenman, which he believed to be a pure expression of Stel, but in reality are embellished.
Diagonal stays to stiffen deck, looking back to Roebling and in fact constructed by the Roeblign wire rope company.
Even cross stays over the roadway on the Deer Isle Bridge

Again note the towers
The Bronx Whitestone, too flexible in its original form
6-42 bronx-whitestone bridge with stiffening truss_150dpi.jpg

Had a stiffening truss added

Note attempt to preserve the profile of the cables.

Stays also added

A decision is whether stiffeners should go above or below the deck
Modifications to Deer Isle, which were executed by Roebling and Sons, inspired new thinking about bridge forms
Critique the aesthetics of Ammann’s and Steinman’s towers
The idea was that a sufficient interlacing of the cables should provide suitable stiffness.
This was put into practice in San Salvador, El Salvador with the San Marcos Bridge

Norman Sollenberger design with the Roebling company
Combined multiple span profile of the San Marcos.
Compare to Bay Bridge

Performed well until blown up in civil war in 1982.

Designed Normal Sollenberger
A new way to deal with aerodynamic problems was proposed by the British Engineer Gilbert in his 1964 bridge over the Severn River.

The deck, of concrete rather than steel, was formed into a streamlined profile.
Note diagonal suspenders and large span
Streamlined deck section being placed
Completed Severn bridge has slenderness without trusswork

2961 feet 1966

The deck is also very torsionally stiff

The diagonals tend to damp oscillation

The deck does not experience wind oscillations, but does move under traffic loads, making durability an issue.

Lacks the clutter of Roebling’s diagonal stays
Freeman Fox was also responsible for the Bosporus Bridge in Istanbul

3270 span 1988

The only bridge that connects two continents
Bosporus towers

Freeman Fox also built the then worlds longest at the Humber River in Britain, now surpassed by Scandis and Japanese

Bosporus towers are concrete, but sleek and light, as opposed to earlier masonry forms
Recall Ammann’s first Hudson river proposal which had light metal towers
Influenced by Brooklyn and its architectural adherents Lewis Mumford, he decided to put concrete and stone over the towers.
St. Johns Bridge of Steinman with gothic metal tower.

1931  1207 feet
Is the gothic form appropriate for a metal structure?

"If you asked me which of the bridges I love best, I believe I would say the St. Johns Bridge. I put more of myself into that bridge than any other bridge."

DB Steinman
Even strange underneath the deck

Look at the anchorages
Steinman rightly ridiculed Ammann’s attempts to cover over his steel towers, but Ammann responded by stating that at least his forms were structural honest.

Ammann sought towers to look like Brooklyn, but was thwarted by the economic constraints of the great depression.
The GWB would have presented an entirely different face to the world had it been covered over in stone.

The myth has arisen that Ammann did not want the masonry, but indeed he did.
Here is the bridge today, brilliantly lit by night.

The style is awkward though because of the requirement of holding up all the stone panels which would have been required in the sheathing. Nothing similar has ever been built again.

Is this a masonry form in steel?
Towers being built by a vertical cantilever method
And eventually topped out, ready for cable spinning.
Cables produced by spinning of wire strands by the Roebling Company as for Brooklyn and Humber
http://www.lighthousemuseum.org/nylights/lred.html

Book by hildegarde swift
The GWB

Spoken of by architects as not a work of beauty but of utility, but this was also thought proper to the time

BB, with light deck and heavy towers was the icon
6-69 golden gate bridge_150dpi.jpg

Was surpassed by the GG in span

Note narrow roadway, and very high towers.

4200 feet towers 500 feet above roadway 1937 opening

Towers sheathed in smooth steel
Very tall towers

Change in form above and below deck
The Chief Engineer, Joseph Strauss, had a strange aesthetic vision he was working from,
And it can be seen often only in segments

The bridge interacts with its surroundings
We return now to the East River and briefly to the story of Steinman
Steinman made a proposal to rehab the bridge in the 30’s by removing the diagonal stays and the central elevated walkway.
6-79 steinman brooklyn bridge cross section
proposal_150dpi.jpg

Note use of aluminum
The depression stopped the plan, and Steinman proceeded to read up on the history of the bridge.

Social: again the depression saves us

He was eventually convinced of its epic nature, and eventually did win a contract for the rehab. But did so recognizing that the “Brooklyn Bridge is Sacred”

He left the structure alone
Thus, it was the humanistic study of history by an engineer which saved the bridge so that in 1989 it could be celebrated in all its glory.
6-82 brooklyn bridge with fireworks_150dpi.jpg

Grucci Brothers
It’s proportions, except of the deck, are reflected at Washington Heights, but most importantly it taught Ammann the lesson that structures must not imitate or cloak themselves, but rather must be an expression of their era.

In his later works, especially that at the Narrows, Ammann achieved the ideal.
Steinman proposed a bridge over the Narrows.

Steinman was Ammann’s only real rival at the time.

Ammann would later span this body of water with his Verrazano bridge.

Here the deck is extraordinarily slender, with almost no stiffening.
Steinman on the other hand chose to design his towers with architectural embellishments which have nothing to do with the scientific purpose of the structure.
Steinman bridge tower. Reminds us of the Clifton proposal of Telford
Verrazano bridge

700 foot towers

4260 span
My opinion of this bridge completely changed when I saw it up close for the first time
Verrazano cables example
So much so that he was eventually awarded the Presidential Medal of Science