Documentary
Silver Bridge disaster and its legacy

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Francesca Hunt
It's 1928 and suspension bridges are being built all across America. New designs and new materials make for rapid construction..... This is the Silver Bridge, crossing the Ohio River at Point Pleasant, West Virginia on its opening day.

Walter Carpenter
My father was Vice-President of the corporation that built the Silver Bridge, it was a wonderful time to be a young American boy. The Roaring Twenties, they called it, and America had...had never been as prosperous, they just thought nothing but the best in the future and a wonderful time for America. The St Mary's Citizens Band marched at the opening of the Silver Bridge... and my father and mother went to that opening, and it was supposed to be a very gala event, but unfortunately right in the middle of the parade, to have a rain and everybody was running and trying to get out of the rain, it dampened the fervour of the thing and the historic impact of it.

Francesca
Shortly after work commenced on the Silver Bridge another bridge, almost identical in design, was constructed at St Marys, about 70 miles upstream from Point Pleasant. The bridge was formally named the 'Hi Carpenter' bridge...

Walter
It was really ready for a big thing to happen at St Mary's, and people were just rousing to welcome this new thing called a bridge crossing the river at St Mary's....

Francesca
In a suspension bridge, the uppermost supporting chains, strung from tower to tower, are members in tension and they exert a downwards force on the towers. The deck is supported from the cabling system using a series of vertical hangers. These hangers are also in
tension. The bridge should be designed so that the degradation of any one tension element of the structure doesn’t immediately lead to collapse.

Nowadays, suspension bridges use cables spun from many individual wires but, in fact, the suspension chains in the Hi Carpenter and Silver bridges were formed out of long lengths of steel, with holes drilled out at either end. These ‘eyebars’ were put together in much the same way as the links in a bicycle chain…..A bolt is used to join the eyebars together. The resulting joints in the suspension chain can then move in response to the forces placed on them…..

Walter
The bridges were both painted with an aluminium colour, and described as a beautiful silver colour, although the St Mary’s Bridge never lost the name, the Hi Carpenter Bridge It always had that, never alluding to the paint at all. But the Silver Bridge was very proud of that silver sheen that they got from their aluminium coat, and when the bridge was even repainted, every time, so far as I know, always silver, or aluminium, but always referred to as a silver bridge. But the word aluminium and the fact that the Silver Bridge will be painted aluminium, I think, had more of an impact on the psyche of the public than did the fact that it was steel.

Francesca
But after barely 40 years, the design and materials used came to haunt them. On December the 15th, 1967, the bridge fell in less than 1 minute, with the loss of 46 lives….. A 20 year old eyewitness at the time, was Charlene Wood…..

Charlene Wood
I was actually on the bridge when it fell that night. I was going home from work, and a trembling an…of the bridge and a…a noise that you couldn’t…I couldn’t even describe what the noise was like, but I realised that maybe something had hit the bridge, and I decided I wasn’t going to cross it, so I threw the car in reverse, and as I was backing, the car stalled on me, but it kept going, and when I was able to get it stopped, the bridge had fell in front of me, and my wheels was on the ledge here.

Francesca
What was the cause? Was it an accident, carelessness, or inadequacy in the design? The problem couldn’t just be that this bridge was a suspension bridge using eyebars because that was a known technology with many contemporary examples.

Francesca
The city of Pittsburgh has three suspension bridges spanning the Allegheny River. Known collectively as the Three Sister bridges, all employ eyebars in their suspension chains.
were constructed at much the same time as the silver bridge and are clearly still standing. They do, however, have a marked difference in their design. This one is the 6th street Bridge. The eyebars are configured together in clusters; meaning that several eyebars are used to form each chain and so the failure of any one eyebar won’t precipitate a collapse of the structure. In fact, the steel used here is of a lower strength than that used in the silver bridge but these bridges are said to have a safety factor of at least 2; that means that they’re designed to support more than twice the greatest expected load.

Tom Vena
The Three Sister Bridges were built in 1928, and they were expected to last 100 years, and at the rate that they’re going now, I’d expect them to last 125 years. The major difference between the designers of the past and the designers you have today, the members that were designed on…on steel structures were over designed where the steel members only needed to be an inch today, well back then they would make them an inch-and-a-half, so you had a…that half inch of material that could actually deteriorate before it even impacted the structural capacity of the bridge.

Francesca
With each eyebar weighing several tons, assembling them into suspension chains was no easy undertaking. But clustering them together had become a time honoured technique because, that way, a degree of redundancy comes from the way that multiple eyebar assemblies provide multiple load-paths.

Photographs from the time of construction, along with the engineering plans, are still preserved in the local county archive….

Bill Connery
This is a plan view of the Sixth Street Bridge, it’s approximately 995 feet long and 77 feet high.

And it gives general notes to the contractor or the erector on the assembly of the plan in giving the manufacturer’s name of the American Bridge Company.

Francesca
The Pittsburgh- based American Bridge Company was able to employ the practice of building from either bank using a cantilever principle. It was necessary to stabilise the eyebars in each arm with additional diagonal braces – until, that is, the two arms met and the whole structure became independently stable.
Each eyebar cluster was of course clearly specified in the engineering plans…
Bill
This sheet here shows you the assembly of the eyebar and the number of bars that are in the assembly which the pin goes through.

Francesca
The pinning, or ‘threading’, was itself a difficult undertaking because of the tight tolerance between the pin and the eyebar holes. The material used was standard annealed mild steel which is susceptible to corrosion; like many steels.

Also, each eyebar contained high levels of tensile residual stress from the manufacturing process and that residual stress could be significant at the points where the eyeholes were drilled out. A combination of tensile stress, a material like mild steel, and the corrosive environment of a bridge exposed to the elements (and industrial pollution), can lead to stress-corrosion cracking.

So, incorporating more material in the form of multiple eyebars makes the overall design of the bridge safer against factors such as these. The construction engineers in Pittsburgh knew what they were doing and could rely on their own tried and tested expertise. At this time, the American Bridge Company also went on to construct both the ‘Silver’ and ‘Hi Carpenter’ bridges. However those bridges were engineered by a different designer, who embraced a new high strength, high carbon, heat-treated steel which, presumably, he thought meant that you could build a less substantial structure. Undoubtedly he expected lower ‘live’ loading than in Pittsburgh. But each bridge was a much longer span and so the loads at the tops of the chains in the towers would have been greater than in the bridges in Pittsburgh. The towers themselves were less substantial structures as well. Yet, the designer felt sufficiently confident in the new material to proceed.

The new design did have a safety factor of 1.5 when they were built but that didn’t account for the increasing weight, and amount, of traffic that each bridge would carry - as cars and lorries were to become heavier and more prevalent with time…

Jack Fowler - a resident of Point Pleasant at the time of the disaster, now runs the local museum.

Jack Fowler
The new bridge, of course, it was owned by local people, and they publicised and promoted it as a very high-strength material bridge. So, the residents had no reason not to doubt that it was not going to be a nice strong bridge, similar, though thinner in design, not the big chunky bridge that existed in some of the other areas, but they had complete confidence in it. And,
uh, this nice silver shiny bridge that we had here, uh, people loved it, and we, throughout the 39 years of existence, people had pride in the Silver Bridge.

Francesca

Following the silver bridge collapse, it was imperative to identify the cause precisely and identify the safety-critical parts of the structure. The big problem facing the investigators was that 90% of the bridge was submerged in fast flowing river!

Jack

The next day, people came from every place, the state, the Federal Government, Ohio, and West Virginia. They had crews in here, the National Guard. And they were out trying to drag and recover the...recover bodies, and they were bringing in the Corps of Engineers’ derricks, boats to start removing the steel.

Well, after they recovered bodies, they wanted to reconstruct the bridge. Um, as they pulled pieces out, they numbered them, marked them, and then they took them and laid them all out in a field to try to find the culprit, what happened, where the failure was.

Well, when they recovered this...the 330 eyebar, when they found two pieces, that’s when they started realising that one of those must have fractured and separated or blew apart and caused the failure. So they focused on that. And I think, from the investigation, that appears to be what happened, we, that’s the analysis that we received about the...the failure, and that’s the one we promote and talk about here at the museum.

Francesca

Most of the material that was recovered from the scene has long gone but the museum did save at least a sample of an eyebar assembly; albeit one that has been cleaned and painted to look like new.

Pete Lewis

This is a typical eyebar joint from the Silver Bridge, which was rescued after the disaster. Um, it comprises a central pin over which the eyebars would have been pivoted, and the whole assembly is encapsulated by the very solid end caps, which themselves are attached by one-inch bolts through the centre of the pin. There’s some interesting evidence of pitting corrosion on the bearing surfaces. This would be the bearing surface of the pin over which the eyebars would rotate, and there is considerable pitting under the track of one of the outer eyebars, and also underneath the cap, even deeper corrosion pitting caused during its lifetime on the...the bridge itself.

Francesca

So what were the weather conditions on that evening of December the 15th 1967 and how was the bridge being used at the time?
Charlene
The weather was kind of chilly. There were snow flurries coming, and it was getting dark. It was around, uh, well it was time when everyone was getting off work, in the evening time.

Jack
Traffic lights on a bridge change the patterns of the traffic flow. Once it changes then you've got all the traffic that's backed up, and they come, a wave of them rush across the bridge, and whatever is in that line, that's the load that you're going to get at that time. And it was on both sides and it worked both ways because, as you can tell from our model that there were a great many coming through from that last change of light in Point Pleasant.

Charlene
When there was heavy traffic on the bridge, there was a motion of going up and down, but I was told that that was normal, so I wasn’t afraid of the bridge.

Jack
The bridge, I don’t think anyone ever crossed it that they didn’t feel movement. Uh, that was a discussion of the community, of the area, because it…it…there was always swaying. It had the up-and-down motion from so much weight on it, and everybody always said wow this bridge is going to fall someday. But then you look back at the design, it was a different design, and we felt that it…it…because of the design it had that built-in motion so to speak. So, you talked about it, but did you worry about it, no, but the motion was there, we experienced that personally.

Pete
This is where the bearing surface would connect with the pin, and it’s, uh, from roughly a position, um, a…at right angles to the shank of the bar where the critical brittle crack, which brought the bridge down, actually started. On the inner bearing surface, there is extensive pitting corrosion, very similar to the one on the corresponding part of the pin, and also traces of fretting marks caused by particles of rust wearing away the surface as the bearing moved.

Francesca
The eyebar that failed, number 330, was positioned on the Ohio end of the bridge on its northern side. Back at the West Virginia end… Charlene Wood was approaching in her car…but, with the failure of that eyebar, she was heading into trouble. …

Charlene
As I stopped, the bridge was coming forward like dominos, swaying back and forth, the tower went to the north when it fell, and as I was seeing all of this, unbelievably, didn’t know what was really happening. I did know what was happening but it just hadn’t registered yet
Francesca
So what did the forensic investigation conclude had happened to make the bridge fall?
Well, eyebar 330 was defective because it had particularly high levels of residual stress left after its manufacture. The design of the eyebar assembly meant that water could pool at the bottom of the eye-hole, and the combination of the tensile residual stress and a corrosive environment had caused a stress corrosion crack to form. Hidden away, the crack had grown slowly, over 39 years, until it was about 3 millimetres long. Also, the steel used in the eyebars had a low toughness at the near-freezing temperatures on the night of the disaster, making it susceptible to brittle fracture. Under a combination of the high live loading on the bridge and the reduced toughness of the steel, the relatively small crack caused a brittle fracture of the eyebar. At the point of failure, a brittle crack grew almost instantaneously down to the outer edge. This overloaded the upper side which separated with some signs of ductility.

The resulting asymmetric load on the pin caused it to twist, and the single eyebar that was left vibrated off the other side of the pin, at which point the chain was completely severed. The adjacent tower, being destabilized, started toppling and fell to the North. The road, below, twisted over and the other tower was pulled down into the river as well.

Jack
What we thought about after the event was how it was inspected, and if it was and you found something, then what do you do to replace it, how do you...how do you get in here and replace one of these eyebars, or one of the joints if suddenly there is corrosion or you sort of found failure, and how do you go about replacing that. But I guess that...that the people at the time had so much confidence in the process of this new high-strength steel that that wasn’t a fear, and I’m sure they built in factors, but, you know, we found out later that it wasn’t as purported to be.

Francesca
Following in the wake of the Silver bridge disaster, one immediate legacy was that the Hi Carpenter Bridge was closed.

Jack
The sister bridge, it had to be closed because it was a similar design, the same company built it. Um, we know now that, uh, they knew there wasn’t any way to inspect it and to, to correct any findings that they might have. So public opinion, uh, almost required that bridge to be closed to vehicular traffic.

Walter
So I sneaked through the bars of the barrier and walked across the bridge and the people that were waiting to get some way to cross, they just followed me like little chicks following a mother hen and there were just a trail of us but after Dick asked me, he said, “Aren’t you afraid to cross the bridge,” just to show you how the people were affected by the falling of the Silver Bridge, that they thought that bridge could fall at any time.

Jack
I suppose a case could be made for not having closed the St Mary’s bridge as soon as they did. It had different use, you know, it didn't have the traffic lights at the end, it didn't have the interstate traffic that our bridge had here, uh, the tractor trailers, all the heavy loads that it carried. There could have been means of inspecting, uh, to find if there were failure, if there was failure on the bridge, if it could be used in a different manner, but I believe that public opinion would not have accepted that, there was too much pressure because of this terrible disaster we had here, I think public opinion would have overridden whatever they may have felt.

Walter
They couldn't get it out of their minds, the fate of this bridge was sealed. The National Transportation Safety Board had no other recourse than to say they had to condemn the bridge because they couldn't prove it was safe, and they were no doubt right in coming to that conclusion.

Francesca
So, apart from the subsequent demolition and removal of the Hi Carpenter bridge, the Silver bridge disaster did at least have a lasting legacy in terms of bridge safety in general...

Tom
When the Silver Bridge collapsed in 1967, President Johnson established National Bridge Inspection Standards, which are the guidelines that are used throughout the United States for all bridges that are inspected.

The National Bridge Inspection Standards require that every bridge be inspected on a two-year frequency, and if that bridge has any problems, it's increased to 12 months, or it could be once a month depending on how severe the problems are with that structure.

Francesca
The 3 sister bridges have already been inspected over 20 times and they will continue to be checked for safety...

Tom
In the past the designers had designed this bridge to last 100 years with a factor of safety around two, and due to the heavy loads that are travelling across the bridge today, that factor of safety has probably gone down, but it's still a safe bridge to travel.

To replace these particular eyebars because they’re in tension, you’d have to design another support system to support it while you’re removing it. So you’d actually build some false work, it would be another bridge next to the exact same bridge that you have, and then remove that false work when you’re all complete.

The different techniques that we use to inspect the steel members would be, um, non-destructive testing where we can x-ray the metal or we can use a sonogram where you use a gel over top of the metal with a sound probe.

In the near future we’re going to make some minor repairs to hold us over until we have time to develop plans for a major rehab on the bridge, and that major rehab we’re going to replace the deck unclear and all the steel members that are deteriorated and paint the structure over again.

Francesca
In America alone, there are over 1,000,000 bridges and thanks to Silver Bridge, they all now receive regular inspection and maintenance. In the case of the 3 sister bridges, redundancy was built-in from the outset in the form of additional eyebars, reducing the criticality of highly stressed joints.

It’s just as important today for those engineers responsible for designing and maintaining bridges to be aware of the need for redundancy, where the inevitable weakest links occur in a structure. And also, knowing those weakest links, to protect them from the effects of corrosion and fatigue and thus ensure the integrity of the structure.