The Riddle of the Tay Bridge Disaster

Forensic Engineering

Melissa Berry
A theory that does involve the full complexity of modern analytical techniques has been put forward by Pete Lewis, a professor of forensic engineering.

Peter Lewis
We reviewed, as a team, the various major disasters worldwide in the Victorian/Edwardian periods and really up to the Second World War. And the Tay Bridge disaster stands out, in a way a bit like the Titanic disaster. And as far as disasters in this country's concerned, it is the worst, and still is the worst structural disaster ever.

All the evidence to me points towards vibration dynamic effects being much more important in this collapse than has hitherto been appreciated. All the analyses at the time and the analyses, computer analyses, I've seen quite recently rely on static analysis of the bridge. But, in fact, in a dynamic situation, life is much more complicated and structures can oscillate and we know oscillations can cause failures.

The classic example, of course, is the Takoma Narrows in the States, where the then longest suspension bridge in the world, failed in a, quite a low wind a forty mile an hour wind, I think it was, which was blowing at a very regular speed and created dynamic vibrations in the carriageway of the bridge and, in effect, it was resonance and the energy was transferred from the wind to the structure and the amplitude of vibrations in the structure became larger and larger until the material just could not withstand it any further and the bridge collapsed totally.

Looking back to the Tay Bridge, I think that there may be similar dynamic effects which were effecting its stability.

Melissa Berry
This latest explanation has only been possible because of the exceptional quality of the photographs taken at the time of the disaster.

The original exposures on large glass photographic plates can reveal a wealth of detail which has not been analysed before.

Peter Lewis
Of particular interest to us were the close ups of the partly standing piers and there were two of these, piers one and three. Now these are important because there are in intact parts here but also partly failed parts. Could they give us the clue to what happened just prior to the complete collapse of this structure?

This is a lug that would have supported a tie bar, which is running from east to west. In other words, if a structure is oscillating from east to west then it is these tie bars here, the east west tie bars, which will have to support the strain.

The stability of the entire bridge is dependent on these lugs. Now why should that be? It's because these lugs are the connections between the tie bars. Now, it's the tie bars which hold the cast iron columns together.

Now wrought iron is a very tough a very ductile material, a very good material to put under tension because it can absorb a lot of strain. But cast iron is a poor material to put under strain, particularly in tension because you can suffer the problem of sudden and catastrophic failure.

My speciality being in plastics and composite materials, my first inkling on seeing these very brittle fracture surfaces with areas of discolouration was to refer the matter to a Forensic Metallurgist.

Ken Reynolds
As a metallurgist I've spent a long time looking at broken bits of metal to ascertain the cause of failure, particularly in terms of road accidents, for example. Did it break as a result of the collision or did it break as a result of fatigue?

As soon as I saw these photographs I realised that this must be a case of metal fatigue, certainly taken a major role in the collapse of the bridge.

Fatigue invariably starts at the surface, or just below the surface of the component. It never starts at the centre. And it starts at the surface whenever there's a small notch or some kind of depression which acts as a localised stress concentrator.

If you burn a hole through the material, then the stress lines can't pass through the hole, they have to go round it, and they concentrate on the outsides of the hole. And that's where we'd expect the fatigue failure to start.

Now, if we look at the piers from the Tay Bridge, we find the holes are where the fractures began and the holes were tapered and the bright areas, which I interpret as being the signs where they've been fatiguing, start from the edge of the hole and they progress steadily into the remaining cross section until there's not enough there to take the loads. And it's the stress concentrating effect of that hole was instrumental in the fatigue starting where it did.

Melissa Berry
So the evidence from the photographs points to the detail of the lugs being the primary cause of the collapse. All three theories agree that a brittle material - cast iron - was completely inappropriate for a structure like the lugs involving tension.

But putting a hole in this material concentrated the stress by a factor of three and on top of that, by leaving the holes for the bolts tapered and not drilling them straight, all of the stress was focused on a very small part of the lug increasing the likelihood of any fatigue cracks. Some cracks had been noticed in parts of the cast iron during inspections but the repairs were inadequate.

Even though we now know much more about fatigue, errors in design and maintenance still contribute to engineering failures.