Wobbly start to the millennium


image: www.freeimages.co.uk

Almost 100,000 people walked across the Millennium Bridge when it opened on 10 June 2000. Two days later it was closed. It was closed because it wobbled.

All bridges have some natural sway but the Millennium Bridge swayed more than it should. Some people said there was a design error and the engineers hadn't carried out sufficient tests. Others said the huge sway couldn't be predicted.

Whatever the facts, the engineers immediately began working on a solution. Allen Paul, Director, Arup, was one of the engineers involved. "Arup led the work of universities and various private companies to find the cause of the wobble, and to find a solution," he says. "This resulted in a greatly increased understanding of the causes, and to the solution of dampers being added to the bridge to prevent the movement."

During the process the engineers worked closely with the British Standards Institution. In the end the unforeseen wobbly phenomenon - which goes by the catchy name 'Synchronous Lateral Excitation' - was included in a modified British Standard Code of Bridge Loading. Any future bridge builders will now be able to carry out stringent tests to make sure their bridge won't suffer the same shaky shenanigans.

Allen adds: "British Standards are fundamental to bridge design. They set out basic criteria about which loads the bridge can carry, and what analysis has to be carried out to prove its adequacy and safety."

The Bridge is now fully-functional, allowing people a wobble-free walk across the Thames. Though never in danger of collapse, it's gone from a potential calamity to a great bit of engineering. And a sight seeing tour of St Paul's Cathedral in now minutes away from a trip to the Tate Modern.

Bridging the divide

Bridges are everywhere. You've all seen them, you've all used them. You may have walked on a small, wooden bridge across a stream, or been driven across a huge steel construction between England and Wales.

They're pretty amazing things. Many people will have looked at a bridge at some stage in their lives and thought, "How on earth does that work? Why doesn't it fall down?"

Four main types of bridge

The beam bridge, which is basically a horizontal beam supported at both ends by 'piers', would normally be used over short distances. The further apart the piers, the weaker the bridge becomes. This means it has a short 'span' - you can, of course, add another pier somewhere in the middle and make the bridge longer. It's the simplest bridge form; if you've ever laid a plank of wood across a stream then you've made yourself a beam bridge.


picture courtesy of www.undiscoveredscotland.co.uk

Although beam bridges are usually used to span short distances, the structure is also used in some of the world's longest bridges. As long as you can keep adding piers, you can make the bridge as long as you want. Sometimes, though, it can be hard to add extra piers - perhaps the water is too deep, or the ground too soft.

Then there's the more complex truss bridge. These are constructed with many triangles, usually made from straight, steel bars. One of the most famous truss bridges is the Forth Bridge in Scotland (see picture, left).

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It has rigid arms that extend from both sides of two piers. They're held in place by diagonal steel tubes. The arms that project toward the middle are only supported on one side - they're called cantilever arms. They support a central span.

The third bridge type is the arch. Arch bridges are naturally very strong. Back in the Roman times they were built out of stone. Nowadays, steel arch bridges can span about 250 metres - that's five Olympic-sized swimming pools.

Finally, we have suspension bridges. These structures have the longest span. There's one in Japan - the Akashi Kaikyo Bridge - that's almost four miles long. Its main span is about 1.5 miles. There are bridges that actually cover longer distances but the Akashi Kaikyo has the longest point-to-point connection without a pier or arch underneath.

Which bridge?

Deciding which type of bridge to build depends on numerous factors. What's it got to cross? How far has it got to go? What's going to travel over it? Then you have to decide what to make it with.

If you want an attractive feature over your garden pond then a wooden arch will be sufficient. But if you want to cross a large river and add a train track to the bridge, you're going to need something much stronger. And all the parts will have to be joined.

When the design's been drawn up - and you've used some physics and maths to work out what forces will act on the bridge - you can start thinking about materials. When that's been decided you can begin building.

image: Helen Boyd

If you can't get over it

Bridges go over things. But when we want to go under something we need a tunnel.

Tunnels are actually quite similar to bridges. They have a number of forces acting on them, and must be strong enough to withstand those forces.

Before digging a tunnel you shouid take soil samples and conduct test drills. By conducting such tests you're able to make a good judgment about what tools to use.

Then there are three steps to making a tunnel. Step one is the dig - this is usually done with huge borers.

The second step takes place while you dig - and it's essential. You have to support the ground around you to make sure the whole thing doesn't collapse.

Finally, you have to line the tunnel. This is the finishing touch and can only be done when the tunnel is structurally sound.

Through mountains and under rivers

The way in which a tunnel is made depends on its location. The types of forces acting on the tunnel vary depending on what you're tunnelling through.

If you have to get to get through a mountain of rock, then a top-of-the-range tunnel boring machine is in order. But if you want to go through much softer ground, you could use a cutter that simply slices through the ground.

Some underwater tunnels are made by digging a semi circular channel on the river-bed and submerging ready-made, waterproofed tubes.