The Arch Never Sleeps
Forces in Masonry: Ely

Narrator:
How can you find out the shape of a particular line of thrust? Well, there is a good use of mechanics for modelling a thrust which Robert Hooke described in 1675. He said that an *"arch stands as a loaded chain hangs"*. Here's Francis again with his wobbly arch in pieces.

Francis Evans:
There's the shape that it's formed with the chain which is of course what Hooke said, *"the arch stands as the loaded chain hangs"*. And even if I take one of the weights – I'll take this big one – and hang it on say there, the chain has resolved itself into this shape, just the same as the shape that we had on the arch when the arch was standing.

Narrator:
There are three forces on the hanging voussoir with its additional load. The downward weight gives rise to tension forces in both directions along the chain. If you compare the compression forces generated by the same load on the standing arch, you can see that they have the same magnitude, although the compressive forces are reversed in direction. The principle really works, even for finding the internal thrusts of a three-dimensional object like the dome on St. Peter's Basilica in Rome. 250 years ago there were worries about the dome's stability, so a cross-section was drawn and divided up, each piece being represented on a physical chain by an appropriate size of bead. Inversion of the chain's shape proved that the thrust line was well within the structure.

Francis Evans:
Would you like to come and feel this…?

Narrator:
As long as the force remains within the arch, it will stand.

Francis Evans:
Can you feel the thrust there? Yes?

Narrator:
But the thrust won't necessarily be contained if the ends move too much.

John Trapp:
We're at the West End of the cathedral now and originally it was symmetrical, wasn't it?

Jacques Heyman:
That's correct, yes.

John Trapp:
So what happened?

Jacques Heyman:
Well, there were two transepts – one to the left, one to the right – but the one to the left collapsed in about 1200, we're not quite sure of the date. You remember this end of the cathedral was finished about 1190, so for ten or twenty years apparently we had the transept to the left there.

John Trapp:
So why did it fall down then?

Jacques Heyman:
This is a question which is related to the soil conditions. We've been talking about the forces in the masonry, the thrusts exerted by arches, the necessity for keeping the forces within the masonry, and so on. But of course the cathedral as a whole is sitting on the ground and the ground gives way.

Narrator:
What happened to the missing transept at Ely can't be known precisely now.