The lifting operation above one of Spain's busiest roads turned out to be more complex than anticipated

A STITCH IN TIME

An unusual lifting operation over a freeway used by over a million vehicles per day gave engineers cause to scratch their heads when a deck section refused to shift, reports **José María Sánchez de Muniáin**

In theory, the equipment installed on a bridge across Madrid's M30 freeway should have lifted the 13m-long, 18m-wide span of reinforced concrete with ease. However, with sensors indicating that the maximum load capacity of the bridge was rapidly approaching, as was the time to reopen Spain's busiest freeway beneath, the on-site engineers were faced with something of a mystery.

The 105m-long Avenida del Mediterráneo Bridge is a concrete bridge with two symmetrical concrete decks, each 18m-wide and consisting of two central isostatic spans supported by seven longitudinal concrete beams. Opened in 1959, it was the first crossing over the busy M30 ring road, marking the entrance to the A3 highway that connects the Spanish capital to the city of Valencia.

Although in 2010 the bearings on the bridge had been locally repaired following damage caused by historical water penetration, it subsequently became clear that a complete replacement of the original bearings supporting the south deck of the bridge was necessary.

In April 2017 an emergency repair project was undertaken by Sarens and structural engineer LRA on behalf of bridge owner Madrid Calle M30, with works awarded to maintenance specialist Tecyrsa in July. Sarens arrived on site on 5 September; the original schedule envisaged a project duration of 44 days from start of works until reopening of the bridge.

The main milestones of the project entailed the overnight partial closure of the freeway during the weekend to enable a span of the bridge to be lifted 4m into the air; the exposed bearings would then be replaced over the course of the following days. Once complete, the span would be lowered and the process repeated for the second span.

The lifting method that was initially considered used a cantilever gantry with concrete counterbalance weights; this was rejected due to logistical difficulties that included the presence of a nearby tunnel, which would have made the use of self-propelled modular transporters impractical. The traditional approach of supporting the spans with falsework had been discarded due to the importance of maintaining the busy M30 freeway open to traffic as much as possible.

The final solution selected consists of a gantry standing on the deck of the

The gantry supports four strand jacks connected to two steel lifting beams under the deck

bridge close to the piers; on top four strand jacks connect to two steel beams under the bridge via cables that run through the deck. The lifting capacity of each jack is limited to the size of the strand bundle, which is in turn limited by the size of the gaps drilled through the deck, which are in turn limited by the available space between the deck's supporting girders. With a nominal maximum lifting capacity of 450t, in the case of this bridge each strand jack had a lifting capacity of 200t.

José María Martínez Gutiérrez, technical proposal manager of Sarens Spain, highlights that lifting a span by 4m and not only swapping the bearings but also repairing the half-lap joints beneath, is not an operation that is often carried out.

A half-lap joint, often used in woodwork, involves cutting out a rectangular section off the upper section of one end, and then joining it with another section where the same sized shape has been removed from the lower side, thereby creating a seamless fit. It is a type of joint commonly used on bridges of this time.

One of the challenges for this project was executing the lift during a single night. Eleven hours allocated for the task inevitably turned into nine workable hours, by the time freeway closure operations had taken place. In that limited window of opportunity not only had the lifting system to be fully installed, but also the section lifted and then manoeuvred to lightly rest against the body of the gantry, to avoid any free movement during bearing replacement works beneath. Each of the seven longitudinal concrete girders of the bridge had small wooden supports along the 21.5m-long lifting beams, and these had to be aligned perfectly in order to distribute the weight of the span evenly during the lift.

The first unexpected challenge came early on in the lifting operation, when the gantry system was being installed on the bridge. "We found that something was not fitting. Imagine, we had seen on the plans that it was 12m long and almost 19m wide, and this divided by seven longitudinal girders. We had six spaces where we could drill the deck to pull the lifting cable without making contact with the girders. We had planned for the gantry supports to be centred between two of these girders in order to distribute the weight equally between the seven girders, and we had planned where to drill the four openings for the cables.

"When we started drilling it was found that the opening were not where they should have been," says Martínez. The deck width shown on the bridge's old plans, it turned out, was nearly a metre less than in reality.

As result of the mismatched dimensions, some of the openings into the concrete deck had to be wider than originally planned. As for the discrepancy in weight of the section, fortunately this had been taken into account from the start: "For all these old concrete bridges, which carry smooth reinforcement bars, the weights provided are never as precise as those on a new bridge or a composite bridge. We knew that the bridge would weigh something like 360t, and we gave it a calculation weight of 450t. The gantry we used happened to be capable of lifting up to 800t," explains Martínez.

When it came to the lift itself, the old bridge had some further surprises in store. "We had an estimated weight of the bridge and when we started to lift, we saw that one side lifted with the expected weight, even slightly less, but the other side wasn't moving. And as much weight as we picked up, we were getting close to the maximum weight limit for the bridge," says Martínez. Previously it had been calculated that the maximum load that could be supported by the bridge sections under the gantry legs was a total of 530t, or 132.5t per gantry leg. During the lifting attempt, a maximum weight of 325t was measured as being transmitted by the two legs situated at the section that wasn't moving.

After numerous attempts and lifting point combinations during the early hours of the road closure, operations were paused while a closer inspection could take place: "We then noticed these bars that had become free on the side of the span that had lifted slightly and we thought, 'this span has been stitched'."

As the span was already being supported by the lifting system, over the next two days, apertures could be made over each girder without the risk of the span falling down. This revealed that the span, rather than being simply supported at the half-lap joint, instead carried a number of vertical 30mm-diameter bars. Three such bars formed a stitch between each supporting girder and the half-lap joint, numbering 42 in total. "They were not in the plans and what seems to have happened is that at one end they had become loose, perhaps by contraction of the concrete or action of the deck, but the other end had remained stitched to the joint," comments Martínez. "Tecyrsa used hydro-demolition to expose the bars and clear them from concrete girders, so that for the next attempt we would only be working against the friction of the lower sections of the bars that were still fixed to the bridge support."

Two days after the first attempt, a second took place: "We again arrived close to the maximum weight for the bridge, but we could see that the section was lifting a little bit. We stopped and again tried to expose the bars further. In the second attempt, when we got to 97% of the maximum allowed load for the bridge, and just before reaching the latest time of closure for the M30, we noticed a small jump. Three bars had become free and the load had reduced by 15 or 20t, and then the rest followed in a domino effect," recalls Martínez.

Prior to the second and final lift, an in-depth inspection was carried out while the first span's supports were replaced with 18mm-thick neoprene bridge bearings. The survey suggested that there were no bars present in the next section. With the overall programme at that point a full week behind schedule, this came as a relief. "But the client and the municipal authorities were fully aware of the surprises that had arisen and were happy with how these had been dealt with on a day-by-day basis," comments Martínez.

Thoughts are now turning as to whether the same lifting technique could also be used on the other crossings over the M30, many of which share the same typology and which may require similar works. Martínez is confident that the same lifting method could be used with longer or wider spans by simply upscaling the equipment or number of strand jacks. The main factor, however, is that the lifts be controlled and monitored with a high degree of precision. "If sensors and monitors had not been used here, the operation could have resulted in damage to the entire span and/or in the concrete support girders. It would have been a serious matter resulting in weeks of delays."

The second lift was executed without any difficulties in early October; works began at 11pm and the operation was completed by 5.45am. As predicted, the half-lap joints and supporting girders of the second section were not stitched together