The new bridges will carry the ring road over marshland in Rodoanel on the eastern side of São Paulo *(Marcelo Delfino)*

URBAN RING

São Paulo's new ring road will finally reach completion this year, bringing relief to traffic congestion. Helena Russell reports on construction progress on one of the final sections

Severe traffic congestion is one of the characteristics for which the Brazilian city of São Paulo, the world's sixth most populous, is famous. Unsurprisingly perhaps, as it does not have a ring road and hence the traffic on ten major highways has to find its way across and around the city.

But construction of the city's Mário Covas Rodoanel Beltway is due to be completed this year, with the final link closing a 177km-long ring road that was given the go-ahead more than 15 years ago.

With the ring road complete, a 40% reduction in truck traffic in São Paulo is expected to be achieved, with the ring road intercepting vehicles on the city's major highway arteries, and offering an alternative route around the city, or to Santos Port. The road is due to be finished before the Fifa World Cup begins later this year.

The main objective of the project, which was given the go-ahead for construction in 1998, is to improve the quality of life in the greater São Paulo area by eliminating heavy traffic and reducing accidents which involve dangerous goods, as well as controlling pollution.

Such problems are exacerbated by the more than 1.1 million vehicles that drive into São Paulo every day, damaging roads, causing the famous congestion, traffic jams and pollution. Once complete, the ring road should improve the situation by diverting more than 300,000 of these vehicles around the ring road.

Construction of the road has been divided into four sections; the western section, which is 32km long, was completed in 2002, whereas the 61km-long southern section was finished in 2010. The eastern and northern sections are under construction at the moment, and are due to be completed this year.

The 44km-long northern section is being built in six parts, and this part of the route includes seven tunnels. Construction of the 45km-long eastern section of the road began in August 2011; it runs through six municipalities in Greater São Paulo.

At the Rodoanel section of the new ring road, two movable scaffolding machines designed and manufactured by specialist Berd, and featuring the company's patented optimised prestressing system, are currently at work building the parallel bridges that will form the two carriageways. The viaduct spans are part of a 1.6km-long section of the route which crosses marshland. By comparison with some of the machines that Berd manufactures, the machines at Rodoanel are relatively modest in scale, but all the same they are managing to build 120m of new bridge deck each week – two 30m spans each – working on a seven day cycle and on staggered cycles.

A total of 92, 30m-long spans will be built by the Berd machines, 46 by each MSS; this will be achieved in 23 steps, with each machine building two spans per cycle. The machines are 90m long, formed of five sections.

Main contractor Contern is working ahead of the machines, installing 2m-diameter piles on top of which the piers of the viaducts are constructed. Contern is responsible for construction of the whole of this section of the project, which is 45km long and forms the final section of the São Paulo ring road. Meanwhile specialist contractor Construgomes is responsible for operating the Berd system on the site.

The main contractor chose to use this particular construction method because the viaducts are being built across a flood plain and marshy land, making it difficult to bring materials and equipment to the construction site at ground level.

Assembly of the first machine began in April 2013, and it started operation in June the same year. The second machine arrived at the site the following month, and began construction in September. When *Bd&e* visited in mid-November, the first machine had completed construction of some 14 spans, with the second machine not far behind, having built 10 spans. Two months later the first machine was on the 20th span with the second machine on its 16th.

The machines are owned by main contractor Contern – they were designed and

built specifically for this project. Once the project is completed, they will use the same machines on other bridge construction projects – either by adapting the machine to suit the bridge design, or altering the bridge design to suit the machine, such as by adjusting the spans, which is sometimes the most cost-effective option.

At Rodoanel the machines are designed to allow for maximum construction efficiency, being able to lift the steel reinforcement cages and transport them as they moves forward to the next construction phase. One of the most difficult parts of the construction process, as Construgomes engineer Pedro Marçal explains, is lowering the steel rebar cages for the main span girders onto the rebar that protrudes from the top of the piers. This is 32mm diameter reinforcement so adjustment takes time.

Berd's 'organic prestressing system' on these machines incorporates four cables, connected from the jacks at the centre to the front and rear of the machine. In this case the construction takes place on a 2% uphill slope, requiring some braking action. The formwork which is used for construction of the deck superstructure is suspended from the main girders of the machine by a total of 80 Dywidag bars, and these adjust the level of the formwork by means of jacks.

Operation of the formwork is carried out by the hydraulic equipment located at the centre of the machine – this equipment moves the jacks which open and close the formwork at different stages of the construction process.

The formwork on each machine is composed of a total of ten pieces – four for concreting on each of the two main spans and a further two pieces that are used to form 20% of the subsequent span, onto which the machine clamps when it moves forward. The bridge alignment has a radius of curvature of approximately 700m on plan, which is accommodated by the presence of a pivot at the centre. During the relocation procedure, both sections of the machine are aligned in a straight line. Once the machine has moved forward sufficiently, and the central section is in the correct position, the pivot point enables the ends of the trusses to be aligned correctly with front and back piers. The actual procedure of moving the equipment takes two hours.

When *Bd&e* visited the site in November, each casting cycle was taking seven days to complete. Since there are two machines, one working on each structure, and each machine casts two spans at a time, the rate of progress is an impressive four spans per week. The most time-consuming part of the construction process is the assembly of the reinforcing steel for the subsequent spans – it takes two or three days to complete, explains Marçal. By staggering the operation of the two machines by three days, the subcontractor can manage construction of both the bridges with a single team of about 80 working two shifts.

During concreting the Berd system adjusts the tension in the cables of the machine to retain the correct vertical alignment, which enables construction of a more slender and efficient structure. The bridge cross-section is a straightforward deck with two edge girders, the latter each incorporating four prestressing cables. Once the concrete has been poured, the cables are first stressed to 70% of the total load after 36 hours, with the full load being applied after a 72 hour period from the end of concreting

The machines each complete two 30m spans every week *(Marcelo Delfino)*