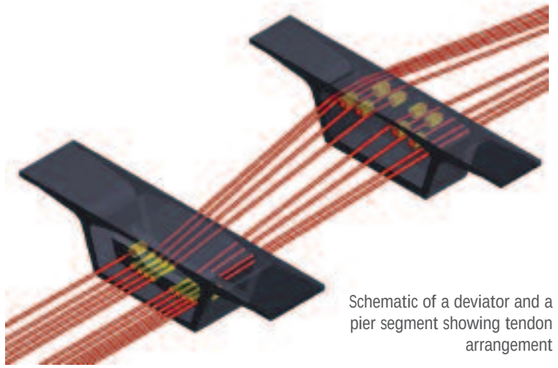


Schematic of a deviator and a pier segment showing tendon arrangement

Israel embraces external tendons

Consultant Finley Engineering Group is providing final design and construction engineering services for six segmental bridges on Israel's Road 431 project - the first in Israeli bridge construction to use external tendons. Finley used Lusas Bridge software to analyse and optimise the pier and deviator segment diaphragms for the imposed loadings whilst keeping the segment weight within the 65t lifting capacity of the contractor's equipment. As a result of the design, both owner and contractor benefited from simplified precasting details, thinner sections, rapid erection procedures and improved long-term durability.

Israel has built more than 25 segmental bridge structures in the last 20 years. But despite the country's considerable experience with segmental bridges, these six bridges on one of the interchanges on the 21km-long, design-build-operate-transfer venture will be the first in Israeli bridge construction history to use external tendons. The 12.5m-wide bridges have span lengths ranging from 30m to 66m and consist of 501 precast segments with a total deck area of more than 18,000m^2.

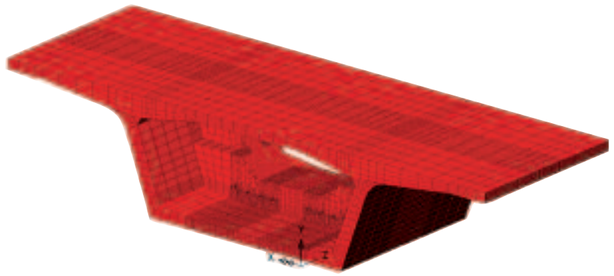
Road 431 is one of the lateral access roads to the Cross Israel Highway 6 and actually constitutes the southern traffic artery of the ring road surrounding the Greater Tel Aviv Metropolitan Area (Gush Dan), consisting of Ayalon Highway in the west, Highway 6 in the east and Road 531 in the north.

The road connects Rishon-Letzion in the west with Modi'in in the east.

Contractor Danya Cebus had a tight construction schedule in order to meet concession agreement requirements and project financing goals. As a result, Finley proposed the use of external tendons to allow for simplified precasting of the segments, reduction in segment cross-sectional area and foundation loads, fewer tendon stressing operations and a reduced design schedule.

Finley worked with the contractor during the final design process which began in February 2006 and resulted in the casting of the first segment in July of the same year. As well as the rapid construction schedule and budgetary restrictions, the contractor also required the consultant to consider detailing aimed at enhancing the long-term durability of the structure, since these bridges must be maintained for 30 years before the consortium transfers the ownership to the government.

Due to the span lengths and size of the segments, Finley technical director Jacques Combault proposed a combination of internal and external tendons to maximise the efficiency of these precast box girder bridges. Internal tendons are used in the top slab in support of the crane-based balanced cantilever construction, and external tendons are used on all continuity post-tensioning. This system was developed with the contractor for more consistent segment precasting configurations, rapid installation of continuity tendons and fewer tendon stressing operations.



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The design process included a technical review by Israeli General Consultant to confirm that the external tendon system adequately met the project requirements.

To assist the Israeli engineers in evaluating external tendon post-tensioning systems, Finley produced a technical white paper that included details of previous projects, excerpts from technical articles, and a list of benefits of the external tendons. It also included Finley's analysis-of-tendon-loss scenarios to meet strict bridge security requirements and design methodology for service and ultimate limit state design with external tendons.

The use of external tendons also provided technical advantages in the bridge design, such as increased ductility for flexural moment resistance and a significant reduction in principle tensile stresses in the box girder webs.

These benefits allowed for longer, constant-depth span lengths for the bridges while still meeting the interchange design requirements. "The large anchorage zones required for external tendons made it difficult to keep the pier segment weight within the 65t lifting capacity of the contractor's equipment," says Finley Engineering Group president Craig Finley, "but by using Lusas we easily modified complex shapes and efficiently optimised the internal pier segment dimensions".

Along with the introduction of external tendons, Finley incorporated several other innovations on this project, including the use of diabolos in the pier segments and deviators to simplify the external tendon details. These post-tensioning details will allow the external tendons to be replaced should this be required in the future. The designers also specified the use of pre-packaged grouts, multiple levels of protection and enhanced duct systems to improve post-tensioning system performance.

Finley principal engineer Jerry Pfuntner says: "The segment models created with Lusas Bridge helped the Israeli design reviewers to feel comfortable with the external tendon details. The models showed the stress levels in the box girder webs, bottom and top slabs as a result of the external deviation forces. This helped us to obtain approval and assure all parties that these details would work well under service load conditions".

The use of external tendons on a segmental bridge project is not a revolutionary concept. But, by assessing the contractor's needs and introducing proven segmental bridge technologies to Israeli construction practice, Finley provided recognised benefits to the owner and contractor with simplified precasting details, rapid erection procedures and improved long-term durability.

Craig Finley says: "Lusas Bridge has been a great tool for us on this project, allowing us to produce a design that has major benefits for the client and contractor. As a result, we would recommend its use to others wanting to enhance their in-house design and analysis capabilities." ■

Precast pier segment being lifted in casting yard