Rail research at the University of Pretoria

by Prof Hannes Gräbe

The Chair in Railway Engineering in the Department of Civil Engineering at the University of Pretoria was established in 1992 when Spoornet (now Transnet Freight Rail) initiated a partnership between industry and the University. This partnership revolves around three major aspects: graduate training, continuing education courses for industry, and railway research.

Technology development

One of the most basic needs in engineering is to measure the movement of structures and their components. This often has to be done with high accuracy and at a high velocity.

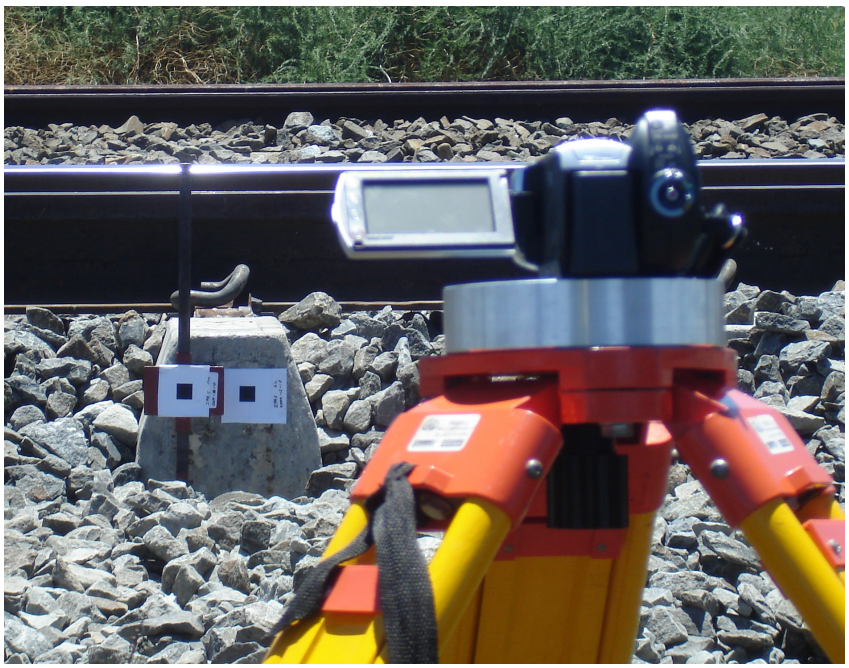
Remote video monitoring (RVM) equipment was developed to address this need and is briefly described. One target, a 2 cm x 2 cm black square on a white background, was fixed to the exposed shoulder of a concrete sleeper in the track. The other target was positioned on a steel rod anchored in the foundation of the track. A video camera was placed three to five metres away from the track where ground vibrations do not influence the measurements. Software was developed that analysed the video recording and produced the horizontal and vertical deflection of the track component. For track applications, the RVM maximum range of deflection measurement was roughly 5 mm with an accuracy of ±10 µm. This cost-effective development enables extremely fast set-up time and solves the problem of finding a stable and immovable reference when doing deflection measurements. Although developed for studying track components, the current RVM equipment that was developed can be applied to any structure where time-dependent measurements are required at frequencies of 1 to 500 Hz. Industry partners for this work are Transnet Freight Rail and TCL Software Solutions.

Another track research focus area is the characterisation of railway foundations. Being a foundation, this vitally important part of a track structure is hidden below the ballast and is therefore not easily accessible. A technology that is already well established in the railway field is ground-penetrating radar (GPR). A GPR antenna transmits a short electromagnetic pulse of radio frequency through the track structure and measures the dielectric constant, the magnetic susceptibility and the electrical conductivity of the medium under consideration. When analysed, this data can be used to detect railway substructures, the degree of fouling of ballast material, the dimensions of subgrade layers and the presence of abnormal moisture accumulation in the track structure.

A video recording of the track and location map, together with GPR results, is a powerful analysis tool in the hands of the rail track maintenance engineer. As the demand on South Africa's rail network increases, Transnet Freight Rail is under pressure to increase the axle load on some of its feeder lines. Future research will use GPR data to classify the substructure based on the stiffness and condition of the subgrade layers, enabling prioritisation of track sections for future rehabilitation. Industry partners for the GPR research are Roadscanners (Finland), Aurecon (SA), E-Logics (SA) and HyGround (USA).

Track research projects

The Chair in Railway Engineering was granted permission to carry out a series of track performance tests on the Gautrain Rapid Rail Link between the Sandton and Marlboro stations. The focus of the research was the transition in track support that occurs when one moves from a rigid, concrete viaduct to a normal track. The same difference in track support is experienced when the train moves out of a tunnel, which is on a slab track, onto normal ballasted track. Differential stiffness at these positions often causes settlement and a characteristic "bump" that develops at the transition zones.



→ *Remote video monitoring is used to measure the horizontal and vertical deflection of a railway sleeper and the foundation below the ballast under train loading.*

→ *Tubular modular track constructed under extreme dessert conditions in Saudi Arabia (photograph courtesy of tubular track).*

A fourth-year Civil Engineering student measured the response of the track at various transitions with RVM equipment. The results quantify the severity of the transition problems and enable track engineers to design mitigation measures for reducing high-track and vehicle dynamics at similar transition zones. The chair has subsequently carried out other field and laboratory tests for the Gautrain on the performance of other track components. Industry partners for Gautrain research are Bombela Concession Company and Isithimela Rail Services.

Although the vast majority of railway tracks in the world are still constructed using ballast, sleepers and rails in the conventional manner, non-conventional track structures are being constructed for specific applications requiring specific performance criteria. Slab track is used in tunnels, on bridges and for high-speed lines that require stable and high-quality track geometry. A South African invention, which falls into the category of non-conventional track structures, is tubular modular track (TMT). The rails are continuously supported on concrete beams, connected to each other by galvanised steel gauge bars. Modules are precast in lengths of six metres and then placed directly on top of a prepared foundation. TMT eliminates the need for ballast and provides a stable track structure with good geometry and low maintenance requirements.

In South Africa, the Chair in Railway Engineering is currently testing and evaluating the performance of TMT installations at Centurion station, Hatfield station, a test section on the Pendoring-Thabazimbi line and a number of TMT turnouts at Ermelo Yard on the coal line. The research focuses on the performance of the system as a whole, but includes detailed investigations on individual components, foundation performance under TMT structures and the transitions between TMT modules. Numerical models are also being developed to broaden the research capabilities of the chair.

Students and staff carry out track performance tests outside Marlboro station on the Gautrain rapid rail link.

As a result of Transnet Freight Rail's support of the Chair in Railway Engineering, a number of research projects are currently being undertaken to investigate specific aspects of railway engineering that require solutions or further development. These research projects form part of a larger project funded by the Technology and Human Resources for Industry Programme (THRIP). One focus is the long-term performance of railway foundations under, among other things, heavy haul loading. A scientific model is being developed to predict the life of a railway foundation based on the details of the foundation design (layerworks and material properties), drainage and environmental conditions, axle load and annual tonnage. This model is especially useful when decisions have to be made regarding increased axle loads and tonnages on existing railway lines. A test site on the coal line was dedicated to the development of this model, and final-year and postgraduate research students in civil engineering visit this site on a yearly basis to accumulate field data and carry out new experiments on the track.

Other research projects for Transnet include the development of a complete formation investigation programme using GPR and other advanced tools, the development of numerical models for enhancing research on conventional and non-conventional track structures and the development of maintenance models for ballast tamping and rail break management. Industry partners for the Transnet research are Transnet Freight Rail, E-Logics and Esteq Engineering.

The Chair in Railway Engineering is honoured to be an active player in the growing railway industry in South Africa. The material and other contributions of industry partners locally and abroad have made it possible for the chair to broaden its research capabilities and make a meaningful contribution to promote the mode of rail transport. It is envisaged that rail will grow and become the preferred mode of transport, not only for passengers, but also for the transportation of bulk, heavy and large-volume commodities.

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