Design and capacity in track construction

Bergen light rail airport connection

Light rail in the city of Bergen ("Bybanen" in Norwegian) is very successful. Its most recent expansion, the new line to the airport in Flesland, opened on April 22, 2017, establishing a connection with the Bergen city center. Adhering to the innovative open-city concept, a ballastless track system was used for new stops and for the airport terminal platform.

Improved connection

Fifteen years ago, the county of Hordaland, the Bergen city council, and the Norwegian parliament decided to integrate a light rail system for Bergen. This system, which today bears the name "Bybanen", is intended to improve the public transportation connection in Hordaland county and especially in Bergen, the county's largest municipality. After the budget for the project was ratified in the parliament, construction began in January 2008.

The first stage of the project was constructed by the municipality, financed by the government via receipts from tolls on the orbital road around Bergen. The overarching infrastructure project became known as the Bergen Program. The project relieved roads, improved the traffic situation, enhanced the satisfaction of both passengers and residents, and stimulated construction of housing around the new light rail stops. The population is concentrated in several nearby valleys that are up to 2 km wide and radiate in all directions from the central city. Light rail thus serves as a multiplier for local transport, relieves the region's most important transport axes, and provides an attractive alternative to automobile transportation.

1: Bybanen's open design uses contrasting colors and materials to enhance safety and visibility for passengers Photo: Bybanen A.S.

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The light rail network was built between 2008 and 2015. The total Bybanen line length is 20.4 km, 40 % of it through tunnels. Top speed in 70 km/h, and the highest grade is 6 %.

The smallest curve radius is 25 m. Such small curve radii occur frequently in the city. Combined with the high levels and frequencies of precipitation in Bergen, these track parameters involve challenging structural conditions and stringent requirements for materials that absolutely must be adhered to during track planning.

The Bybanen Utbygging planning authority is responsible for planning and coordination with other authorities and advances the infrastructure project. It performs both track system design and execution planning for construction work (including excavation and track construction work). Gunnar Levring, Rail Engineer Design Manager for Bybanen Utbygging, points out that planning requires close cooperation with various authorities such as the City of Bergen and the Norwegian road authority. Levring used to work for a large international engineering consulting agency. Today, he works closely with several consultancies that specialize in light rail expansion projects.

2: Rastoelen is one of the new stops on the airport line. Concrete is used for the top layer along the platforms. Increased housing development is typical in areas near such stops (see the right side of the image) Photo: Rail.One

The Bergen Program: Promoting local infrastructure

Today, the expansion project is predominantly financed via the Bergen Program. A positive side effect of a new light rail line such as the newly-opened airport line is the rise in housing development along the streetcar lines. Thousands of new apartments are being built near the new light rail stops. Within a radius of 600 m of the airport connection, there are about 9,000 new apartments [1]. Estimates indicate that investment in new housing is 20 times that of the original Bybanen infrastructure investment.

An award-winning light rail network

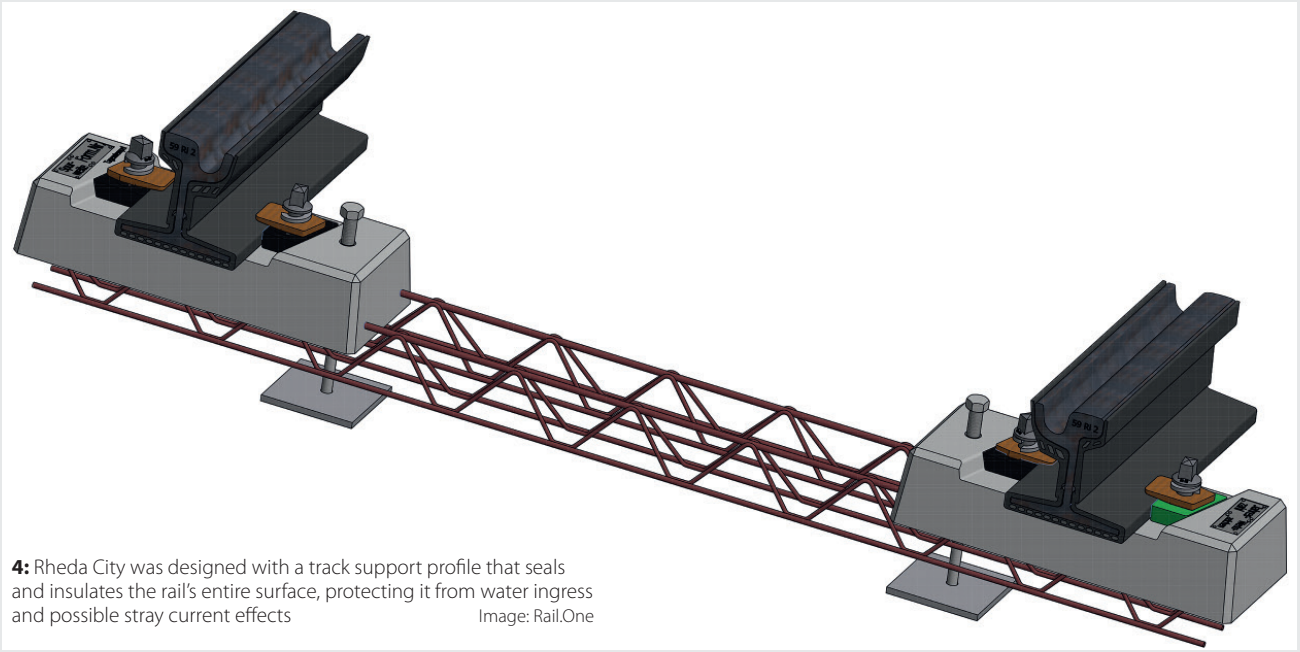
In 2011, the Bybanen project was recognized as "Worldwide Project of the Year". The jury explained the decision by saying that "this fantastic system is a model for light rail projects all over the world" and pointing out that efficient project planning allowed the first line to be built in only two years and within budget. All earlier passenger number forecasts had been exceeded, and the Bergen light rail project, which was originally only a regional landmark, had developed enormous visibility within just a few years.

After this first important prize, which is one of the biggest and best-known for the Bergen light rail project, Bybanen won the "Collective Traffic Award" the next year for developing a new customer group and providing attractive public transportation. The same year, Bybanen won the Norwegian Association for Residence and Urbanism's BOBY award for outstanding cooperation between authorities and the implementation of a high-quality joint project. In 2013, the city of Bergen received the "Urban Environment Award", a combined architecture and environment prize for cities with sustainable environmental improvements. Two years ago, Bybanen won the "Innovation Award for Uniform Design" in the Transport and Furniture/Interior Design categories. The jury explained that "Bybanen is the first light rail project in Norway with uniform design" and called the project "courageous and innovative". The variety of these awards has made Bybanen an international light rail benchmark.

Passenger numbers growing faster than expected

Levring points out that passenger numbers rose by 50 % between 2010 and 2014. 2015 saw 10 million passengers [2]. The average daily passenger total is around 40,000 – 50,000, which is 100 % above the forecast calculated seven years ago. Skyss, the company that is responsible for the ticketing system and timetables, expects another 4 % annual rise in passenger numbers. These numbers indicate that expanding Bergen light rail would be a good idea. The Bybanen network has added light rail vehicles that are 42 m long, each carrying up to 277 passengers.

3: Gunnar Levring is the Rail Engineer Design Manager for Bybanen Utbygging, an authority in Norway's Hordaland county. Bybanen Utbygging is responsible for planning and coordination with other authorities Photo: Bybanen A.S.



4: Rheda City was designed with a track support profile that seals and insulates the rail's entire surface, protecting it from water ingress and possible stray current effects Image: Rail.One

Harmonized: Design and capacity

Bybanen's overarching goals are light rail network safety, long-term stability and reliability, and a positive passenger experience. Levring says that Bybanen's characteristic visual design element is the "open-city approach" – open structures without fences or other interfering elements near the light railway line. Another important element for enhancing safety is the white lines that clearly mark both the edges of the platforms and the transition between street and track. Levring says, "The design offers passengers safety and visibility. It is decisive for customer perception. We have received many positive comments from people with seeing disabilities that confirm this. The contrasting colors of materials, the white marking lines, and the dark outer concrete layer improve orientation opportunities for passengers and safety in general."

Bergen is known for its high rates of precipitation (up to 2,500 mm per year), humidity of up to 80 %, and rapid freeze-thaw cycles. Levring explains, "Because of the local weather conditions, the tracks must be well-protected against water ingress. Wherever buses drive on the light rail line, the roads are salted to facilitate public bus transport. The combination of rain, moisture, and salt can damage the track in the long term. This makes the interface between the track and the road surface a decisive design factor. In the winter months, there is often ice on the overhead lines, and, during service shifts, our service vehicle must remove that ice and the snow that has fallen on the tracks. Maintenance at the new stops along the airport connecting line, including the tracks at the airport terminal platform, consists primarily of high-pressure water cleaning. At the depot in Kokstad, robust track solutions offer reliable track protection against negative influences from chemicals that are used for cleaning the light rail."

5: Rheda City installation at the Flesland airport terminal Photo: Rhomberg Sersa Rail Group

The Bybanen expansion project

The most recent line expansion, the 7 additional kilometers in Stage 3, runs from the Lagunen stop to the Flesland airport. Construction on the light rail line began in 2013. After track construction work was completed and the stop at the Flesland terminal built, the line was officially opened on April 22, 2017. Kokstad, not far from the airport and connected to the airport line by

a branch line, is where the repair and maintenance center– one of the most modern light rail depots in Northern Europe – is located. It has an area of 280,000 m^2, allowing maintenance of up to 80 vehicles, and parking bays for up to 45 light rail vehicles. The depot was constructed in cooperation with Stadler, a company that provides light rail vehicles and was tasked with vehicle maintenance by Bybanen AS, which owns the Bergen light rail network.

Levring describes the method of selecting suppliers and companies involved in the airport connection project. At the beginning of the project, a consultancy was asked to evaluate various suitable ballastless track systems. The goal of the analysis was the selection of a durable, proven fixed-track solution for the Rastoelen, Sandslivegen, Sandslimarka, Kokstad, Birkelandsskiftet, and Kokstadflaten platforms, the Kokstad repair and maintenance depot, and the terminal station at the Bergen Airport in Flesland.

Levring recalls, "The primary focus was on the interface between the track and the road. We wanted to make sure that the road system was resistant to water, moisture, and road salt, that it allowed a precise, robust track geometry during installation and throughout the service life, and that the ballastless track system could be adapted to various surfaces such as asphalt, concrete, and grass. It was also important to us that the experience from the years of use in traffic in the city and surrounding area be available, and that many sound project references with comparable traffic and weather conditions confirm the system's suitability for our purposes. The ideal ballastless track system should have a long service life and allow future maintenance work, such as track replacement every 40 years or so. After carefully comparing the various systems, we decided to go with the Rheda City system. The Rhomberg Sersa Rail construction company installed the fixed-track solution and the concrete sleepers supplied by Rail.One. In the course of the track construction work, concrete sleepers were installed on time for the ballasted track sections and Rheda City for the ballastless track platforms. The Rheda City ballastless track system was also used for the cleaning tracks at the Kokstad light rail depot. I would like to mention that the flexibility and experience of the track construction company is very important. Excavation work often involves delays, meaning that the track construction work has to be performed without much lead time in a tight time window. After completion of the track construction work, the signal system and the overhead lines were installed in the final stage of the project."

6: Rheda City ballastless track system at the Flesland airport terminal platform Photo: Rail.One

Continuously supported track system with isolated rail

The Rheda City ballastless track system was adapted to Bybanen's project-specific requirements in cooperation with the consultants involved. This gave rise to a customized solution that stands up to typical Bergen weather conditions. The Rheda City project for the Dublin streetcar system was used as a benchmark model for the track design.

In the Dublin project, resistance to high levels of precipitation was one of the main criteria. This required optimized insulation of the interface between the rail and the ballastless track. For the Bergen Airport platforms, Rheda City was designed as a

continuously supported track. This track type uses Rheda City bi-block sleepers combined with an elastic track support profile whose rail seal offers protection from water ingress and the possible effects of stray current. The continuously supported track also allows quick, simple installation and gives the superstructure optimum elasticity. This ensures long service life for the rail, the track, and components of rolling stock such as rail vehicle wheels.

System flexibility and stable track geometry

To reduce long-term effects of maintenance work such as correction and repair of gauge-widening effects in tight track curves, and to ensure a stable track structure, the system at the platforms of the new airport connection line were designed to be covered tracks with a concrete subbase. This created a precisely oriented, highly resilient track structure that can stand up to the high levels of precipitation and frequent frost cycles.

In the light rail depot's washing area, the Rheda City ballastless track system was modified to be an open track without covering to ensure resistance to water, oil, and cleaning agents. The Rheda City concept implemented in the depot's washing system includes coated and therefore corrosion-protected fastening system components that exhibit higher chemical resistance and greater stability in the presence of road salt, ensuring a long track service life.

The core components of the Rheda City track system are the modified bi-block sleepers with lattice girders that ensure a solid design for the ballastless track system that is suited to the load conditions and stresses imposed by streetcar and mixed traffic. The system's bi-block sleepers, which are encased in an in-situ concrete slab, and the insulating track support system form a sturdy, monolithic track slab. The adjustable track-fixing system that is pre-installed on the bi-block sleepers allows the ideal track position to be set.

Rheda City bi-block sleepers are available for all track construction types – both Vignole and grooved rails – and for all track widths. The Rheda City ballastless track system can be easily adapted to any track concept – concrete, cobblestone, or asphalt road surfaces, open tracks with exposed rails, and green tracks. Modified bi-block sleepers offer solutions for guide and safety rails and anti-derailment devices. Conceptual designs with three or four rails or tracks with different widths are supported.

After a construction time of 22 months, the main line and the depot was handed over to Bybanen for initial test runs.

Construction stage

During the construction stage, Bybanen had the site manager monitor all work. He checked the status of work and conducted weekly meetings, safety inspections, and concrete material tests to ensure that the material used, the personnel processes, and the work quality met construction regulations and the specified requirements. The Bybanen site manager was supported by a contract manager who researched contractual questions during the construction stage and initiated measures as necessary.

Because of delays, the construction work was performed under a great deal of time pressure. The primary reason for the delays was excavation work such as tunnel construction. The time lost there had to be compensated for in track construction. For instance, track construction work near the airport in Flesland was done at night so that tunnel lining work could be performed at the same time and the deadline Bybanen had set could be met.

Among the unusual tasks was the use of black concrete at the Rastoelen and Birkeland stations. The concrete with a black visible surface had to comply with Bybanen's general safety system and the associated color scheme. Bybanen carefully chose these color specifications after evaluating several color samples. Moreover, the overall designs of the tracks on the main line and in the depot were each adapted to the specific requirements of these two areas. That is why different functionalities were implemented for different systems.

A further challenge was in the construction of the Rastoelen stop, where anti-vibration mats were laid under the Rheda City track system to acoustically decouple the track from the substructure. However, this made it difficult to achieve precise track geometry. The track construction team's expertise and experience resulted in the local implementation of an ideal solution.

The coordination and close cooperation between the supplier, Rail.One, and the Rhomberg Sersa Rail Group, allowed various technical and scheduling challenges to be successfully met. Lukas Mair, Rhomberg Sersa Rail project manager, summarized the project as follows: "We are proud to have once again delivered a quality product on time to a satisfied customer."

After a construction time of 22 months, the main line and the depot was handed over to Bybanen for initial test runs. "All in all, we are very satisfied with the track solutions and the track work that has been done," Levring says.

Outlook

For the expansion levels planned for Stages 4 and 5 of the light rail, close coordination with the city of Bergen will be important, not least because of land acquisition efforts. The Stage 4 expansion line, which is about 10 km long, begins in the Bergen city center (Byparken) and runs west to the Fyllingsdalen district. Stage 5 will begin in Byparken and end in the northern district of Åsane. The preliminary plan calls for the Stage 4 expansion level to open in 2022. Bus traffic and light rail will share road surface in the area of the city center on both expansion lines. An asphalt layer is to be used as platforms, since asphalt is easy to install and maintain.

In November 2016, Light Rail Day was held in Bergen. The event focused on Scandinavian light rail projects and gave many international visitors the opportunity to become familiar with Bybanen's light rail operation. Levring says, "Bybanen is visited by many people from countries all over the world. We are happy to share our experience and hope that other light rail projects will be as popular and provide the same utility for the people they serve."

References

[1] Railway Gazette International, June 2017, p. 16
[2] Solveig Mathiesen, Bybanen project manager, presentation at Bergen Light Rail Day, 11/14/2016