Implementación BIM - Del diseño a la construcción – Puente de Herøysund, Noruega

BIM implementation from design to construction - Herøysund bridge, Norway

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RESUMEN

El proyecto del puente Herøysund en Noruega es un ejemplo del uso innovador de BIM en el diseño y la construcción de infraestructuras. Este puente pórtico mixto de acero y hormigón, de 135 metros de largo, es completamente basado en modelos. El proyecto utilizó metodologías BIM, incluidas la modelización paramétrica, la coordinación multidisciplinaria y herramientas de análisis avanzadas, con un enfoque en capturar y gestionar atributos de diseño detallados para garantizar precisión y eficiencia. Este artículo explora la aplicación de BIM en el proyecto, destacando su rol en la gestión del ciclo de vida, el cumplimiento normativo y la colaboración. Se discuten los principales desafíos, las lecciones aprendidas y los beneficios más amplios de BIM.

ABSTRACT

The Herøysund Bridge project in Norway is an example of the innovative use of Building Information Modelling (BIM) in infrastructure design and construction. This 135m composite steel-concrete rigid frame bridge is entirely model based. The project utilized BIM methodologies, including parametric modelling, multidisciplinary coordination, and advanced analysis tools, with a focus on capturing and managing detailed design attributes to ensure precision and efficiency. This paper explores BIM's application in the project, highlighting its role in lifecycle management, regulatory compliance, and collaboration. Key challenges, lessons learned, and the broader benefits of BIM are discussed.

PALABRAS CLAVE: BIM, Acero-hormigón mixto, Paramétrico, Atributos

KEYWORDS: Building Information Modelling (BIM), Composite steel-concrete, Parametric, Attributes

1. Introduction

The inauguration of the Herøysund bridge, Figure 1, in November 2024 marked the completion of a critical infrastructure project in northern Norway. The bridge, which includes two traffic lanes and a 2.5m cycle/footpath, spans the sea channel connecting the islands of South and North Herøy in Nordland County, Norway.

Figure 1. Herøysund bridge after inauguration

In 2021, the concept phase explored three alternative solutions to address the urgent replacement of an aging concrete road bridge that had reached the end of its design life. Given the project's time-sensitive nature, the design was selected for its construction process.

Nordland fylkeskommune, the bridge owner, started the project with a requirement for full integration of Building Information Modelling (BIM) across all phases of design and construction. Model-based projects are being driven by the requirements of the Norwegian Public Roads Administration (NPRA), Statens vegvesen [1]. They would also be responsible for the digital audit to ensure that the bridge complied with all regulatory, functional, and safety standards

This paper provides an in-depth exploration of the development process from the perspective of the design engineer, describing the application of BIM methodologies to deliver this landmark project efficiently and effectively as an outstanding example of paperless design and construction. It includes a review of BIM technology for infrastructure projects, with particular reference to its use in Norway and a description of the specific BIM methodology used for this project. It concludes with discussion of the main challenges encountered, lessons learned and the benefits of the BIM implementation.

2. Background

2.1 Overview of BIM technology

Building Information Modelling (BIM) is the creation of a highly detailed, digital representation of a construction project, such as a bridge, which can be used to supplement or replace traditional 2D drawings.

The BIM model goes beyond simple 3D geometry by including information, or metadata, for the structure which enhances the model's functionality beyond its geometric and visual aspects. It enables better planning, multidisciplinary collaboration, design, clash detection, construction, and lifecycle management thus improving efficiency and reducing risks.

BIM can refer to both the digital model and to the workflow. As a digital model it includes:

- 3D Geometry

A three-dimensional representation of the structure, including the precise shapes, sizes, and spatial relationships.

- Metadata

Embedded information such as material type, material quality, level of detail, design status, specification description etc., and other data necessary for construction and maintenance.

- Multi-Disciplinary Integration

Integration of inputs from all disciplines, such as architectural, structural, civil, mechanical, and electrical into a single, coordinated model.

When referring to BIM as a workflow, it encompasses the processes, methods, and technologies used to create, manage, and share the information embedded in the model. Multidisciplinary teams collaborate with defined workflows for creating, sharing, and updating the model. The workflow relies on different BIM modelling software (Autodesk Revit, Tekla Structures, collaboration platforms (Trimble Connect, Solibri) and standards (ISO 19650) [3].

2.2 Why use BIM?

The Norwegian Public Roads Administration (NPRA) has been leading the adoption of model-based bridge projects. Key factors driving this change are described below.

2.2.1 Efficiency and Collaboration

Model-based workflows enhance collaboration among stakeholders by providing a shared digital representation of the bridge. This reduces communication gaps, streamlines coordination, and minimizes errors during design, construction, and maintenance.

2.2.2 Improved Design Accuracy

The use of 3D models allows for more precise and detailed designs, reducing the risk of discrepancies that can arise in traditional 2D drawings. This precision is particularly important for complex bridge projects where geometric and structural challenges are significant.

2.2.3 Cost and Time Savings

By identifying potential design conflicts and construction issues early in the process, using clash detection, a model-based approach can save costs and reduce delays.

2.2.4 Lifecycle Management

BIM enables effective lifecycle management of infrastructure. The NPRA aims to create "digital twins" of bridges, which can be used not only during the design and construction phases but also for long-term maintenance and operation.

2.2.5 Regulatory and Industry Trends

Model-based projects align with broader trends in the construction and infrastructure industry where digitalization is increasingly recognized as a best practice. By mandating BIM, the NPRA is ensuring that Norwegian projects remain competitive and compliant with international standards.

2.2.6 Government Initiatives

The Norwegian government has actively promoted digitalization across sectors, including construction and infrastructure. NPRA's requirement for model-based projects reflects a national strategy for innovation in public works.

2.3 Application to bridge projects

The NPRA has been a pioneer in adopting model-based design for bridge projects promoting the use of BIM in infrastructure development. The 643m long Randselva Bridge, completed in 2021, stands as a significant achievement. It is recognized as the world's longest bridge constructed entirely using 3D models without traditional 2D drawings [3].

BIM implementation for the Herøysund project was for all phases and notable as the sole source of information for the Contractor.

3. Project Description

3.1 Location

The bridge carries the Fv828 road over the Herøysund channel between the islands of Nord Herøy and Sør-Herøy in Herøy Kommune, Nordland, Norway (Figure 2). This remote municipality has less than six thousand residents and is situated on the western coast in the Helgeland region, known for its beautiful coastal landscapes and islands.

Figure 2. Herøysund bridge - location

3.2 Design brief

The Nordland fylkeskommune zoning plan included approximately 550m of new road of which 135m was to be the replacement bridge. The bridge was originally envisaged as a steel box girder with spans of 35m - 65m - 35m, directly founded on rock. An alternative with a network arch had also been proposed. The principal client requirements were:

- Minimum 65m span over sea channel.
- Model-based for detailed design project in accordance with the NRPA handbook V770.
- Shipping channel 9m (above HAT) by 30m.
- Three alternatives for evaluation with associated cost estimate.
- Tender documentation in accordance with the Norwegian Public Roads Administration's handbooks R761 & R762 [4].
- Interdisciplinary BIM model for coordination with road design, road signage, electrical, drainage, landscape, geotechnical etc. to which both the consultant and the client have free access.

The final solution was to be assessed on factors such as economy, implementation, buildability, and construction time.

3.3 Specific challenges

A major challenge was the overall period given for both the design and construction phases. During earlier rehabilitation work on the existing concrete bridge over Herøysundet, damage was discovered that made it necessary to build a new bridge within the remaining design life of three to five years and was important for both local residents and commercial traffic to and from the salmon fisheries on Herøy, a mainstay of the local economy.

Further challenges for this project were the remote location and exposed weather conditions. Both needed to be considered during the construction phase and for future maintenance.

The road alignment received gave an asymmetrical bridge geometry with a slight curvature on plan at each end and differing abutment heights. This gave rise to additional challenges in the modelling process.

3.4 Chosen solution

Three options were considered - a steel box girder with composite deck, a network arch, and a composite steel-concrete rigid frame structure with a central arch. All options were based on using steel to maximise off-site fabrication of the superstructure. Deciding factors in the final choice of solution were no piers in the sea channel and the lack of extensive temporary works. The solution was also favourable for future maintenance with clean lines and an airtight box section. The client also favoured the solution due the lower visual impact on the surroundings (Figure 3).

Figure 3. Render of chosen solution

The final design is a composite steel-concrete rigid frame structure with a central arch spanning 75m and two 30m end spans giving a total bridge length of 135m. Two vertical steel frames separated 5.5m are formed by a steel box section with a constant width of 1m. The steel frames support the 11.3m wide concrete deck which carries the two lanes of traffic and the 2.5m wide cycle/footpath (Figure 4).

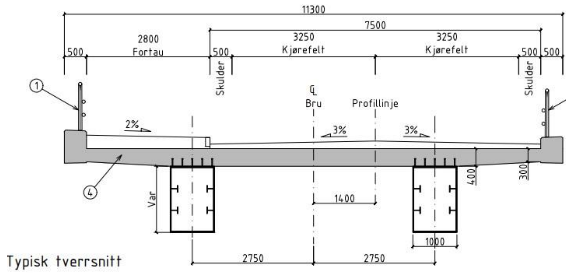


Figure 4. Typical section

The steel arch is founded via a concrete base directly to bed rock. The steel piers are anchored to the concrete base with a system of post tensioned anchor bolts. At each abutment the steel box section is supported on pot bearings that allow for longitudinal movement.

4. Bridge Analysis and Design

The implementation of a fully model-based project allows for a close control with the calculation model. Finite element software SOFiSTiK and Robot Structural Analysis were used for the analysis and design of the bridge superstructure and substructure respectively.

Different global and local FE models were created as follows:

- Global frame: Superstructure, steel arch and composite concrete deck.
- Global shell: Superstructure, steel arch and composite concrete deck (Figure 5).
- Local shell: Concrete deck.
- Local shell: Pier baseplate and anchorage.
- Local shell: Deck support over abutment.

The relevant design checks were performed with the results obtained from the global frame model. The purpose of the global shell model was to calibrate the behaviour of the global frame model and to evaluate in more detail the behaviour of the pier-to-beam connection. Geometry of this global shell FEM copied the exact geometry modelled in BIM, as all shell elements were defined using 2D elements exported directly from the BIM model.

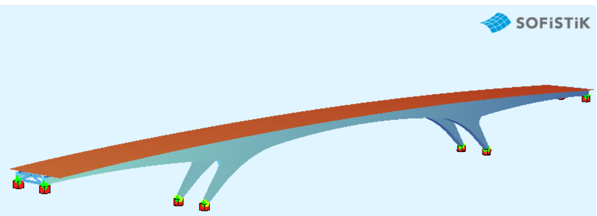


Figure 5. Global shell FE model

SOFiSTiK is a powerful structural analysis and design software suite and incorporates SOFiPLUS as its dedicated CAD/BIM tool for model creation within the AutoCAD environment. Together, they enable seamless integration of BIM workflows for infrastructure projects.

The workflow started with the geometry definition in SOFiPLUS, within AutoCAD, to define key elements and use parametric modelling to facilitate updates and modifications. The SOFiPLUS model was then exported to SOFiSTiK Analysis + Design for detailed structural analysis. This software can perform advanced FEA, including static, dynamic, and nonlinear analysis. The feedback loop to SOFiPLUS allows for model updates. Analysis results were then exported back into SOFiPLUS to visualize stress distributions, deflections, and other parameters. This also allowed the precamber geometry to be precisely modelled in 3D.

5. BIM Methodology

5.1 Introduction

In addition to the native BIM model different file types are used to facilitate the exchange, visualization, and coordination of information within the project.

- IFC (Industry Foundation Classes)

A standardized, open file format that captures the geometry, spatial relationships, properties, and metadata as exported from the native model. It facilitates interoperability, allowing collaboration between disciplines using different tools. The .ifc format is universally recognized as a neutral exchange format and forms the basis for any model-based project.

- SMC (Solibri Model Checker)

This is a proprietary file format commonly used by BIM coordinators for advanced model checking, validation, and quality assurance.

- BCF (BIM Collaboration Format)

This is an open file format used for issue tracking. It can capture issue descriptions, viewpoints, screenshots, and related comments. It links to specific locations or objects in the model but does not contain the full 3D geometry. It is widely used in Norway by the third-party checkers as part of the technical approval process.

5.2 BIM software

5.2.1 Tekla Structures

The native BIM model for the bridge, the primary editable version, was created using Tekla Structures.

5.2.2 Rhino/Grasshopper

Rhino is an advanced 3D modelling software with flexibility to manage complex geometry with an extended functionality via Python scripts. Grasshopper is integrated with Rhino to facilitate parametric design. Used in conjunction with Rhino it can introduce rules-based logic to the design process. For this project, in addition to form modelling, scripts were written to control and assign attributes to all elements.

5.2.3 Trimble

The cloud-based collaboration platform, Trimble Connect, was used at the design phase for collaboration between disciplines (Figure 6) and as the main tool for internal coordination and quality control between the design engineers and BIM modellers.

Figure 6. Combined BIM models including terrain

Trimble Quadri a model-based collaboration platform tailored for infrastructure projects allows for the sharing of the native models and was used by the BIM coordinators.

5.2.4 Solibri Office

This software was used to generate the .bcf files to communicate comments from both the third-party checking engineer, Cowi, and from Statens vegvesen. This digital audit of the BIM model was used to obtain the final technical approval for the project.

5.3 Project phases

Model-based projects require the BIM model to be used as a coordination tool during the design phase, as part of the tender documentation and as a complete set of construction information for the Contractor on site. The BIM model serves as a tool for fabrication, procurement, delivery. Handbook R762 is the NPRA standard specification for bridges and quays [5]. This handbook provides standardized process descriptions and guidelines for the construction and maintenance of bridges in Norway. The BIM model was explicitly linked to this document by the use of code numbers defined for each part.

5.4 Level of detail

Level of Detail (LOD) is a standardized system that defines the reliability of a BIM model element at various stages of a project. It focuses on the specificity and accuracy of the information in a model. The level of detail in a model-based project is implicitly high as all information needed by the Contractor must be included.

Model Maturity Index (MMI) is a broader concept that assesses the overall maturity of a model, including the processes, workflows, and data integration associated and is commonly used in Norwegian construction projects. MMI 200 refers to the concept phase, MMI 350 for the detailed design once interdisciplinary coordination is complete and MMI 400 for production. All parts of the model were given as MMI assignation.

5.5 Parametric design

Parametric modelling uses a set of rules to produce the digital model in such a way that changes can easily be implemented. Scripts were written for this project both for geometric modelling and for a rapid, controlled process for attribute assignation.

5.6 Attributes

All objects in a BIM model have attributes assigned that contain information. These can be standard, predefined in the native model, or User-defined Attributes. User-defined attributes offer flexibility and customization for specific project needs, while standard attributes provide essential, consistent information across all BIM models. The organization and assignation of attributes was fundamental to the success of this project.

At the start of the detailed design phase example attributes were provided by Statens vegvesen. This was based on using an alphanumeric system to organize attributes. Letters are by discipline following the standard system for drawings in Norway. For the bridge construction the letter K is used, V for roads, I for electrical etc. Other requirements were to use Statens vegvesen standard object codes from handbook V770 to link to the standard specification process from handbook R762. Using these guidelines a first BIM manual was created to describe the organization of attributes. Further description of these attributes is given with the description of the model in the following chapter.

6.Description of the BIM models

In addition to the models for other disciplines, road, lighting etc. there were four models produced for information during the construction phase:

- Bridge construction
- Reinforcement
- Precamber geometry
- Construction sequence

6.1 BIM implementation

Two documents were prepared at the start of the project. The *BIM Implementation Plan*, an overall plan for the data flow and information sharing specific to the project, and the *BIM Manual - Description of the discipline model (Construction)*. This second document described the organization of the BIM model, in particular with regard to the assignment of attributes.

6.2 Information object

A general information object was created where overall project attributes, such as the project coordinate system, could be found. Other general attributes, applicable to all discipline models were assigned the prefix A and are shown in Figure 7. are shown below. A critical attribute was the code that linked any given part to the specification based on the Norwegian handbook R762 [4]. This document, which includes both the standard specification and any project specification text, also includes all the quantities.

Attributes

01_GENERELL

A01 Prosjektnavn:	Fv 828 Herøysundbrua
A03 Fagkode:	K_Konstruksjon
A05 Byggefase:	Fase 2
A07 Bru nummer:	18-3205
A11 Revisjonsbokstav:	A
A12 Revisjonsdato:	2023-04-12
A13 Revisjonsmerknad:	-
A14 Produsert av:	Degree of Freedom
A15 Utført av:	AE/FB
A16 Kontrollert av:	KO
A17 Godkjent av:	BO
A22 MMI:	350
A23 Material:	STEEL
A41 Objektkode V770:	85110000
A42 Objektkodenavn V770:	levering-av-valset-stål-og-tilsettmaterialer-for-sveising
K01 Objektnavn:	Stålplate
K02 Ekstra beskrivelse:	Referansetemperatur +5 °C, iht. Prosess 85.2
K03 Byggefase:	8
K04 Materialkvalitet:	Stål S355N
K91 Objektkode Brutus:	D3
K92 Objektnavn Brutus:	Stålkasse
K93 Godkjent ifølge VD:	Godkjent ifølge notat 23/15618-2 fra Vegdirektoratet
K94 Godkjenningsdato VD:	2023-04-12
K95 Vedlikeholdstiltak:	https://bit.ly/3Ko6LXA

Figure 7. Organisation of general attributes

6.3 Bridge structure

This was the principal model (Figure 8) and included all the permanent structure and bridge equipment.

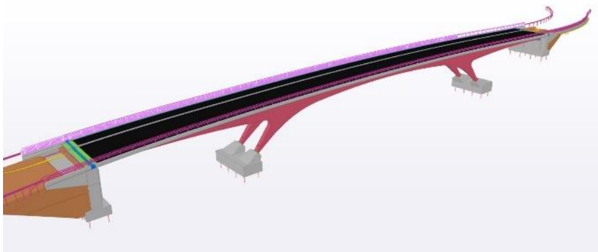


Figure 8. BIM model

In addition to the superstructure and substructure this model included the following:

- Excavation volumes.
- Waterproofing and surfacing.
- Fill behind abutments.
- Railings, both for bridge and approach roads.
- Bearings and expansion joints.
- Cable ducts, earthing, sailing channel signage, levelling bolts.
- Weld details.

Figures 9&10 show more detailed extracts from the model.

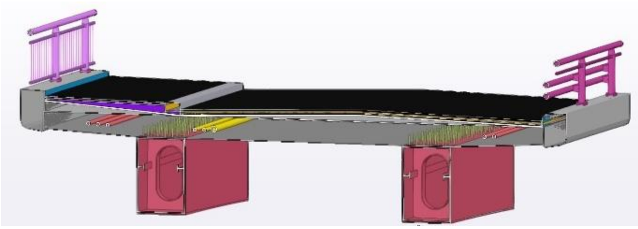


Figure 9. BIM model

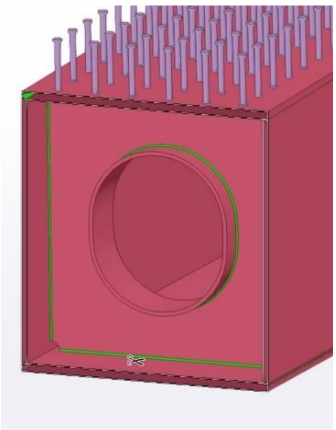


Figure 10. BIM model

6.3.1 Concrete

Concrete forms for the bridge deck were modelled parametrically based on the road alignment. All concrete volumes were divided into and assigned partition numbers.

Typical attributes assigned to concrete elements were execution class, cover and formwork specification.

6.3.2 Steel

Examples of the attributes assigned to the steel parts as defined in the BIM Manual are shown in Figure 11. Figure 12 shows how the attributes then appear in an IFC viewing platform.

Attributt	Eksempel innhold	Forklaring	*Explanation*
K61 Utførelsesklasse iht. NS-EN 1090-2	EXC3	Utførelsesklasse for stål	*Execution class*
K62 Konstruktivt/Ikke konstruktivt stål	Konstruktivt stål II	Se R762 Tabell 85.11-1	*Steel type to R762*
K63 Produktstandard	NS-EN 10025-3	Produktstandard	
K64 Seksjonsdel	S-2-C	Ståldel basert på monteringssekvens	*Steel part based on erection sequence*
K65 Tykkelse	20	Stålplate tykkelse (mm)	*Plate thickness (mm)*
K66 Fargekode siste dekkstrøk	RAL7035	Topplakkfarge	*Top coat colour*
K67 Overflatebehandling	Angitt i den spesielle beskrivelsen i tilbudsgrunnlaget for prosess 85.3	Malingssystem	*Paint system*

Figure 11. BIM manual – steel attributes

Property	Value
K61 Utførelsesklasse iht. NS-EN 1090-2	EXC 3
K62 Konstruktivt/Ikke konstruktivt stål	Konstruktivt stål II
K63 Produktstandard	NS-EN 10025-3
K64 Seksjonsdel	S-1-B
K65 Tykkelse	20
K66 Fargekode siste dekkstrøk	RAL 7035
K67 Overflatebehandling	Angitt i den spesielle beskrivelsen i tilbudsgrunnlaget f...

Figure 12. IFC viewer - steel attributes

6.4 Reinforcement

Reinforcement was exported in a separate IFC file (Figure 13). In Norway it is standard practice to provide the Contractor with a bending list that includes detailed instructions for the cutting, bending and placement of rebar. The purpose of the reinforcement model is to replicate this list with the model attributes.

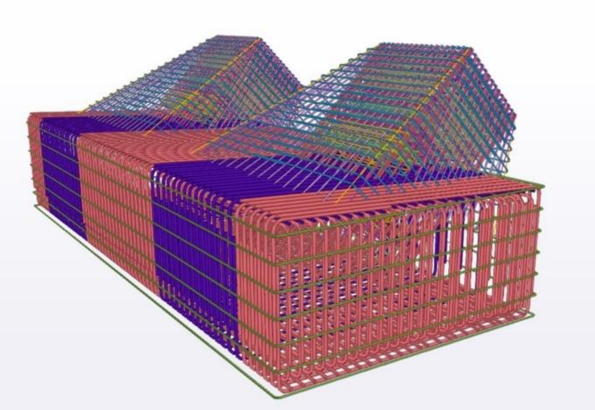


Figure 13. Reinforcement model – foundation

Modelling the rebar allowed for coordination with all anchor bolts and ducts as shown in Figure 14.

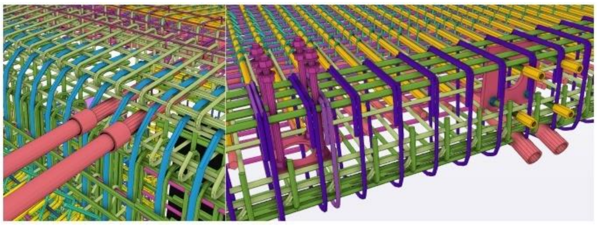


Figure 14. IFC viewer - steel attributes

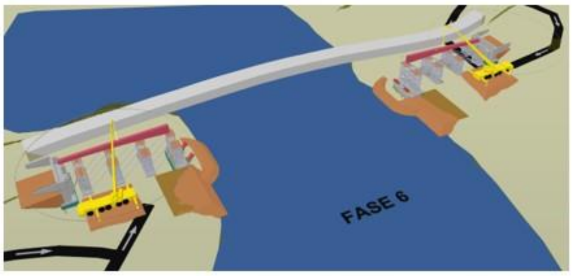
6.5 Precamber

The Norwegian design handbook [5] requires that both the final geometry and the precamber geometry are defined. This was prepared using a simplified model of the volume of the steel box section in the precamber position. This geometric model combined with the main model gave all the information necessary for the steel fabricator to prepare their workshop drawings.

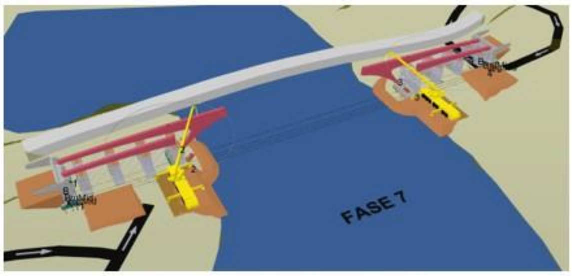
6.6 Construction sequence

A virtual construction sequence was prepared by modelling both auxiliary elements and by the assignation of phase numbers to all parts of the permanent structure. Auxiliary elements used to illustrate the construction sequence were exported as a separate IFC, including cranes, barges, temporary works, and temporary earthworks.

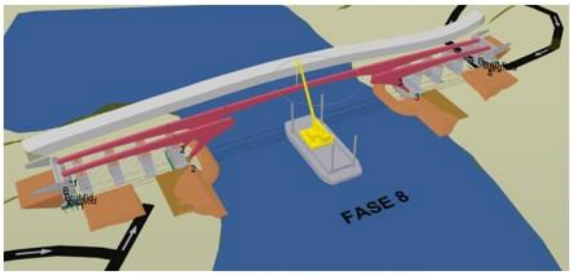
Figure 15 shows views created by selection of phase in both models.



Phase 6: Erection of steel on temporary supports for end spans



Phase 7: Erection of steel – pier section



Phase 8: Erection of steel - central span

Figure 15. Construction phases

7. Challenges and Lessons Learned

Technical, organizational, and collaboration challenges were encountered, including:

- Workflow between project members with widely varying levels of experience in BIM implementation.
- Definition of attributes, their organization and flexibility for changes.
- Transfer of information for attributes from engineer to BIM modeller.
- Optimal level of detail needed.
- Understanding use of the BIM model at different project stages. What information is needed and how will it be viewed?
- Control of changes and quality control.

- BIM implementation in a singular project – less benefit from standard details.

A key lesson from this experience would be the importance of a well-planned workflow and organization of attributes. Degree of Freedom are participating in a working group set up by Statens vegvesen to standardize model-based bridge projects. It is also important to consider the time needed to transfer a singular design into a complete model with all information for planning and construction. This time is clearly offset by the gains to other stakeholders but should not be underestimated.

There may benefits of BIM, both quantitative and qualitative, during the project lifecycle. During the design phase parametric modelling allows for a flexibility to accommodate changes rapidly and link directly to the calculation model. Clash control software anticipates many issues, in particular between different discipline. At tender phase both Contractor and Client can have greater confidence in the quantities. A good BIM model aids considerably for procurement and planning. Visually a 3D model also allows for greater understanding of the project.

Experience in Norway has shown that in comparison with traditional project delivery methods using 2D drawings that there are less issues and variation orders on site for model-based projects. From a design engineer´s perspective a fully model-based project has less scope for errors as there is no duplication of, and possible contradiction in information, as can be the case for 2D drawings.

8. Conclusions

In conclusion, the Herøysund Bridge project highlights the transformative impact of Building Information Modelling (BIM) in modern infrastructure development. By integrating BIM methodologies, the project overcame significant challenges, including remote location, adverse weather, and intricate design requirements, while ensuring precision, efficiency, and timely delivery. The effective management of design attributes and interdisciplinary coordination through BIM facilitated seamless collaboration and enhanced lifecycle management. The lessons learned from this project serve as a valuable reference for future infrastructure initiatives, demonstrating that BIM can streamline complex design processes, improve regulatory compliance, and drive long-term value for both project teams and stakeholders.

Acknowledgements

The realisation of this project is thanks to a dedicated design team including engineers from Degree of Freedom and HRP.

Throughout all stages the client, Nordland fylkeskommune, has provided constant support and understanding to the design team

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