Hoover Dike USA – Experiences with the use of a digital twin in specialist civil engineering

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ABSTRACT

Clewston, USA. Paper is outdated, the digital twin is reality!
This is how evaluations and production optimisations run in a matter of seconds in digital form. The customer is aware of that as well and that is the reason why the customer demand data management on the Herbert Hoover Dike contract. Production parameters are recorded every second by the CSM rig using various sensors and saved in a production file. In addition, all project-relevant data (reports, images, videos ...) are stored centrally and are made available for the customer on a daily basis. All project parties have the possibility to follow the process of the construction site on a digital replica and are able to start control measures for the execution or planning.

The production data are read into the relevant production data management system "b-project", processed, and stored in a standardised database. The production logs, quality checks or overlap calculations generated from this twin are created completely automatically by b-project. The overlaps between the individual constructed Cutter Soil Mix (CSM) elements are required by the customer in three different levels and every 10 feet (approx. 3 m).

No 2D/3D modelling software or other programs are required for the visualisation and calculations. The data and tools are implemented in the software. A data manager sets up the system on the construction site and raises an alarm if there are any quality defects. As a result, location-independent control measures can be initiated in the shortest possible time after the element has been manufactured. All data can be accessed worldwide. In this way, the efficiency of the measures initiated can be traced directly on the digital twin.

A 3D geographical information system (GIS) system opens another form of visualisation and documentation for the digital image of the project. This enables a uniform understanding of the project and visual monitoring of target/actual states.

Keywords: digital twin, digitalisation, GIS, data management system, BIM

1 INTRODUCTION

In the past few years, the execution of project sites has become more and more digital.

At present, there is no system available on the market which is tailor made for the requirements of large and complex specialist foundation projects and visualisation of the functionalities as demanded for worldwide application.

This was the reason why BAUER choose to take this direction to developing an own data management tool for special foundation projects, which can handle the production files of machines from the Bauer Machine GmbH (BMA). The newly created system has a degree of standardisation which creates a company standard for the future and allows for sufficient flexibility to cover multiple cases. Digitalisation has reached the special foundation industry. Not only construction companies have an ever- increasing necessity to extract data, especially production data, but also clients.

At the project Herbert Hoover Dike (HHD), a major project in the US, BAUER Spezialtiefbau GmbH (BAUER) developed a digital twin to satisfy the requirements of the contract and make forecasts about the current condition and future processes of the construction sites. This gives the opportunity to react to problems and adapt to increased productivity.

2 PROJECT DESCRIPTION

With a total area of 1,890 km², Lake Okeechobee is the largest freshwater lake in the US state of Florida. Despite its dimensions of about 56 km in length and 48 km in width, the lake is very shallow, with a 3 m depth on average and moreover has no major natural outflow.

As a protection against storm tides and floods, the existing dam was first extended in the 1920s. Additional canals, locks and dams were constructed.

Since 2007, the U.S. Army Corps of Engineers (USACE), a general command of the US Army, has been responsible for coordinating the refurbishment of the 225 km long dike around Lake Okeechobee.

BAUER Foundation Corp. was commissioned for the first time from 2007 to 2013 with the execution of cutter soil mixing sealing walls for the rehabilitation of the first sections of the dike. Due to the successful cooperation, the Bauer Foundation received further partial orders for the years 2011 to 2022, including for the sealing work on various sewer culverts.

In two constructions stages, they replace first the unsuitable organic materials by more than 35,000 predrill borings and fill it with non-organic backfill. Followed by an installation continuous and homogeneous cut-off wall. This wall has a cumulative total length of over 30 km and consists of more than 12000 panels by a depth of 20m and a width >= 60 cm.

3 PROJECT REQUIREMENTS

3.1 Digital requirements

The U.S. Army Corps of Engineers (USACE) operates and services approximately 740 dam structures, including the associated infrastructure in the USA. For the projects associated with the Herbert Hoover Dike Remediation, the USACE has listed items in their specifications which need to be provided in a digital format. The data exchange is a contractual obligation which has to be fulfilled by the Contractor. Here in Germany as well, more and more construction projects have “Client Information Requests” (AIA) incorporated in the tender documents. These AIA specify which kind of data and in which format it needs to be handed over to the Owner.

To comply with the owner’s request, the contractor compiles a Data Management Plan (DMP) which explains the concept how it is executed and transmitted. Such a plan was also compiled for the HHD project. It describes how the system is implemented and kept up-to-date. The DMP is considered to be a living document; it is updated in regular intervals, and if required, constantly discussed and agreed with the client.

BAUER had already developed an in-house platform to collect and analyse production data and save it in a structured way. In addition to the data transmission to the client, an internal analysing system was created during project execution, which supports the site with varied information and evaluations.

Further, additional tools were supplemented to broaden the project support, which lead to the development of a digital twin of the project that could be visualised.

These AIA specify which kind of information, when and in which format it needs to be handed over. Here, USACE determined two ways of doing so. A GIS-platform as well as data transmission via sFTP. Documents on quality assurance, but also information on construction progress, are examples of the required information. They are, to a large extent, transmitted in an automated way.

The following information has to be handed over in format.

GIS
- production report
- overlaps in different layers
- links to videos (VBs)/photos
- production data (start/stop)
- quantities (slurry)
- depths

Server storage
- pictures
- videos
- reports
- machine data
- test reports

3.2 Personal

The data manager named in the DMP is responsible for the whole data management on the construction site. The data manager also serves as a contact person for the customer in terms of all data-related topics.

On the part of the contractor, data manager takes care of the documentation and processing of the resulting data. This includes the design and accumulating AsBuilt data. The data must be secured, examined, and evaluated. Adaption is possible as well before they are made available to the customer in the GIS and file server in the form of drawings or protocols.

4 CENTRAL DATA RECORDING

The project collects data during the complete execution phase. The model is fed from all areas involved in the project. Data may come from CSM rig, design, but also from specialist departments. The data are archived centrally on the platform b-project developed by Bauer. The data may be retrieved in real time and analysed in various ways.

In order to make the data more reliable, a quality check is required before release, marked as “tested” and then passed on to other systems. By combining the differing sources, we gain advanced evaluation possibilities.

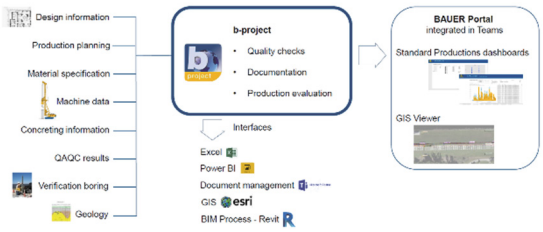

Figure 1. Interfaces of b-project

5 DIGITAL MODEL

Digital twins are the virtual representation of a physical object or system. The task is, for example, to understand, predict and optimise the performance of a plant or process. The aim is to achieve better business results and increase the overall performance of a company. Digital twins are made up of three components: a data model, algorithms and knowledge (Max-Ludwig Stadler, 2021).

On the b-project platform, the complete HHD project is available by means of datasets. They can be for example in 2D and 3D and are always compiled on the basis of the adjusted or latest information. The data may also be transmitted into data analysis systems and can be displayed by diagrams.

On a daily basis, reports are prepared in a Business-Intelligence-(BI)-solution and provided to the persons involved in the project via a portal.

By archiving the data in a system containing the same structure, they can be analysed transversely. In doing so, a wide range of possibilities opens up. The construction progress can, for example, be linked with the quality data. As well, specifications by the client can be compared with the construction data and automatically verified for compliance.

By archiving the data in a structured way, comparisons can be quickly drawn. The project can generate steps for a better and more effective construction sequence and check directly the effect of the relevant control measures.

6 PROJECT REPORTING

6.1 Tailor-made for recipient groups

As the construction process contains a great wealth of information, the digital twin, as well as user-group-oriented evaluations, can be implemented rather easily. Because of the digital twin, it is feasible to process the automatic analysis for various kinds of user groups and to provide it in an easily accessible environment. The data is analysed – if necessary – several times a day.

To make sure that the users widely accept the tool, its usage has to be kept simple. For Bauer's digitalisation strategy, it was decided to use Microsoft Teams by default. That means that for each project a separate environment is created in Teams where the "BAUERdigital Portal" is incorporated. Here, information can be saved via a tiles navigation. These may be linked to applications, such as the GIS-Portal as used in the HHD project or to the reporting system.

In the last years, BAUER has generated standard reports on each major project which uses b-project. They are respectively available for all construction methods, as carried out by Bauer and tailor-made for three main recipient groups. The latter ones are the client level, the management level, the site management, and the specialist departments of the project, as well as the site management on the construction field.

Each project site is able to grant rights for the system on its own. To do so, a simple system was developed. The relevant "owners" of the teams are in a position to administer who to grant which rights and when, i.e. they do not need any support by the IT department in this respect.

Management and client
- Simple visual display, giving an overview of construction progress
- Target/actual overview by means of speedometer

Project management
- S-curves with target/actual display
- Forecast on completion date
- Display of delays

Site staff
- Detailed information on production
- Quantity information on consumable material
- Information on deviations during production

Figure 2. Example Business-Intelligence evaluations of the project

6.2 Consistent quality despite of high number of elements

The more elements there are at a project, the more effort has to be taken for quality assurance, documentation, and reporting. The platform b-project as used by BAUER reduces this effort. The number of elements is irrelevant here, which represents one of the greatest advantages of introducing a standard system. The reason is that logic of creation such documents is implemented in the system. As soon as the data has been entered and checked, the creation can be completed without manual intervention.

Quality and construction progress are documented according to the time interval as required by the project. Apart from the documentation, the system also supports optimising the construction sequence by its timely reporting system. Here, data from the current production may consistently be compared with the target requirements of the project. If applicable, countermeasures can be taken. Control measures are directly displayed, and further corrections are possible.

The overall quality of project documentation as well increases that way. It is constant and comparable throughout the complete execution period. Changes in the reports are applied for the complete construction period and are not only visible starting from the day when the change was made.

Moreover, mistakes in the planning phase or the construction sequence can be quickly and easily identified and directly rectified. Thus, there is less potential for subsequent defects. As well, optimisation of elements can be identified, and it is also possible to develop potential for improvements for subsequent projects. The system immediately compares the geometry as planned with the one of the components installed in 3D view, thus enabling a visual check of the geometry. This comparison can be done daily. The information on the elements installed is automatically displayed in the CSM rig.

7 VISUALISATION

7.1 GIS-System

In a geo-information system, data of various origins are linked with the relevant location in the model. In this way, it is possible to visually locate project-relevant documents and information. The attached documents, videos, and photos can be opened and downloaded via a web browser at any time.

USACE required during the tender phase that data be provided on a GIS portal. Here, it was specified in the contract which data was to be retrievable in GIS and in which period of time they have to be available after completion of the individual elements.

An interface was programmed which ensured that the data is transmitted directly from b-project into the GIS-system, which is spliced in two different working layers.

7.1.1 Plan view

Is the top view of the georeferenced online map. Each element constructed can be selected manually and visualizes the general production information. Here, the client requires submittal amongst other information of the respective position data, start and stop times, the slurry quantity as consumed as well as the final depth of the individual element.

The required documents are automatically generated in b-project and then archived in a uniform structure and under a pre-defined glossary in the GIS system. The following information was required by USACE and implemented accordingly.

The production reports of an element have to be linked with the twin displayed in the GIS-model. This means that each constructed element has a virtual counterpart; the relevant construction report is attached to this counterpart in the model.

For each element, overlap drawings have to be created. They should to be generated for the depths as specified in 2D-view. The drawings, photos, and videos are also linked to the relevant elements and placed at the relevant position in the GIS where they originated.

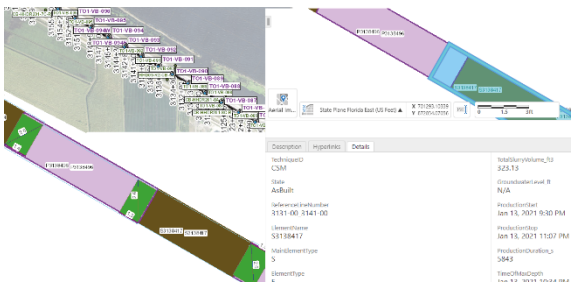

Figure 3. GIS plan view

7.1.2 Profile view

Exploration borings, verification boring of injected material and QAQC test results are paramount in this view.

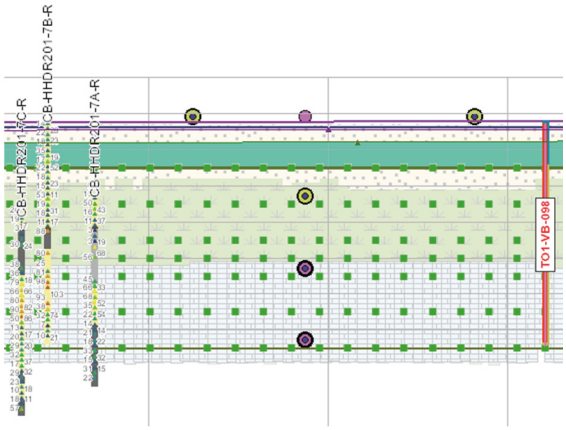

Figure 4. GIS profile view

In Figure 4, the circles demonstrate QC results of tested material. Circles are placed on different heights, which stand for the place/height of sampling. Test results and testing documents were displayed as well.

Before the project was starting, BAUER executed on different stations exploration borings to identify the existing geology. Based on these results, the construction site profile is optical classified in different soil layers. All relevant documents are linked in the GIS. One of the biggest parts is the demonstration of the verification boring of the As-Built elements. Videos which are recorded after the boring were attached on the correct spot and can be easily accessed by the client.

7.2 Documents and Drawings

Due to the client's requirements, various further documents and drawings in 2D are also necessary. These are mainly displayed in pdf-format. In this case, we are talking about production reports, overlap calculations, construction reports and overlap drawings.

The data as needed for these reports are made available in a structured way and are archived in the b-project database. The resulting drawings and calculations may be generated at the touch of a button. Expert knowledge on CAD or a similar drawings software is not required.

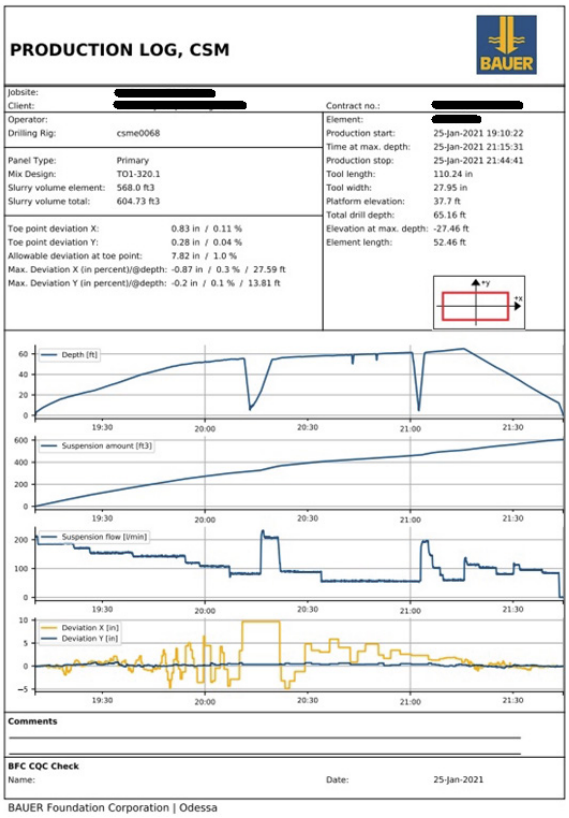

Figure 5 Production protocol CSM

Overlap drawings may be generated at any time and variably. In Figure 6, overlaps of a secondary element with both primary elements are displayed. The required cut-off heights (Top, Mid, Bot) were pre-defined by the client. Position data and deviation data of the individual elements are the basis of these drawings as saved in the machine data and archived in the system database.

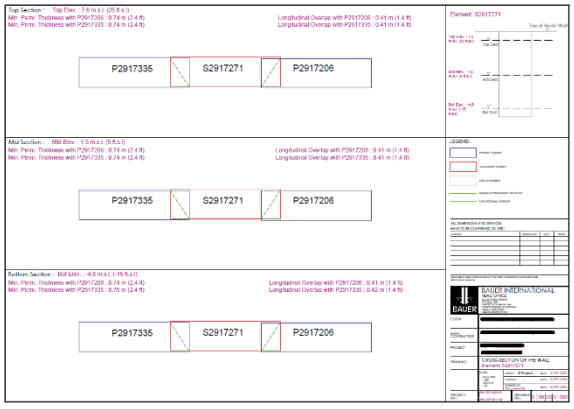

Figure 6. Automated overcut calculation drawing

Everything is provided, taking minimum effort and almost in real time. The document information record, as required by the client, can be retrieved at any time and is archived in a structured way. An Add-on was created to compile the documents, which displays the necessary documents and information when needed.

7.3 As-Built in Revit

The design data are recorded in b-project. They are available in list format and contain all information as required for the production. These data may also be used to generate a design model in the modelling software Revit.

b-project processes and archives in a structured way, the production data as collected by the CSM rig, the so-called “As-Built” information. A 3D-model can be generated based on these data via the relevant interface in Revit. The recorded geometrical data are processed in Revit using a dynamo script and an As-Built model of the elements is compiled. They are used to facilitate comparisons and form the basis for data checks. Here, it is easy to visually spot if the elements were installed at the correct position. As well, it is also quite simple to check if the targeted final depth was reached or if it was exceeded.

8 CONCLUSION

As this tool was developed in-house, it is flexible and can be used adjusted to any projects with little effort. Other features can also be implemented within a relatively short time.

It is also possible to link it to external sources. During the development phase, it was important to generate a sufficient number of interfaces to enable the connection of other systems, if applicable also external partners.

The advantages of using a data management system like b-project are obvious. The system can be used by everybody after a short training; no expert knowledge for drawings, calculations or similar are necessary. As described, a digital twin does not always have to be a graphical interface, but makes life easier. The representation of the resulting data is very clear. A picture is worth than thousands words. It increases understanding and facilities discussion between the contracting parties. The data of the digital twin is stored structured and can be used at any time for necessary evaluations. E.g. between similar projects based on the same geology can be obtained and included in future tenders.

The database of the digital twin is the basis for improvements in construction processes or further development of the machines.

In addition, there is no risk that, in contrast to other types of documentation, the data will be lost due to the termination of employment. The central data storage of the database protects them for later application.

REFERENCES

Max-Ludwig Stadler (2021). “Digital Twin.” https://mindsquare.de/knowhow/digital-twin/ (Aug, 2021)