

ARCHITECTURE, ENGINEERING
& CONSTRUCTION
CIVIL DESIGN INNOVATION



**INNOVATIVE INDUSTRIALIZATION METHODOLOGY
ACHIEVES BREAKTHROUGHS IN CIVIL DESIGN**

This white paper provides a broad overview of the latest innovations and breakthroughs in civil design and construction, as well as the challenges faced and the solutions devised to achieve higher quality and improved efficiency. This paper was written jointly by Dassault Systèmes and the Shanghai Municipal Engineering Design Institute (Group) Co., Ltd. (SMEDI).

GLOBAL INFRASTRUCTURE PERSPECTIVE

With the exponential growth in global population and living standards and the accelerated development of infrastructure to support it, the quantity and scale of civil engineering projects worldwide is constantly on the rise. As reported in Capital project and infrastructure spending: Outlook to 2025, published by PricewaterhouseCoopers (PwC), infrastructure spending worldwide is expected to reach more than US\$9 trillion per year by 2025, more than doubling from US\$4 trillion in 2012. This is particularly apparent in China, the Middle East and LATAM – covering countries like Brazil, Argentina and India where economies are growing at phenomenal speed. According to Global Construction Perspectives, 63 percent of global construction activities will take place in emerging markets, largely driven by China and India, by 2025. As remarked in the PwC report, an additional 180 airports are estimated to be needed in India alone in the next decade.

“In recognition of the unprecedented level of capital required to fund the infrastructure projects, there is greater interest in private sector involvement and public-private partnerships (PPPs)”, says Ryan J. Orr from Stanford University and Jeremy R. Kennedy from Akin Gump Strauss Hauer & Feld, LLP. In the past, the vast majority of the infrastructure projects were initiated by the governments concerned. However, as government budgets get tighter, especially for countries that are politically unstable and with weak government finances, more and more private companies are getting involved in these projects in the form of Public Partnerships or Private Finance Initiatives. These private companies have growing concern about return on investment (ROI) and higher efficiency – in both design and construction – to result in greater and faster profits.

BROAD PERSPECTIVE IN CHINA

The latest innovations and breakthroughs in civil design and construction in China are in the context of two trends. China’s strategy in developing civil design and construction practices is to use Building Information Modeling (BIM) to fuel the industrialization process. The United States, Japan and European countries are already highly industrialized countries and, as a result, have well developed IT industries. China is committed to using BIM as a means of driving the industrialization of construction. This is the country’s ongoing strategy.

In addition, China is shifting from a planned economy to a market-driven economy. In the past, under the planned economy, the Shanghai Municipal Engineering Design Institute (Group) Co., Ltd. (SMEDI), “the civil design institute”, was one of the largest departments in infrastructure design and even was given supreme authority to the degree of specifying details to be used for construction. Now, under the market-driven economy, the civil design institute remains an important function, but its direct influence on entire projects is diminishing, particularly the downstream construction processes. For example, consensus from multiple stakeholders is now required for highway projects before design instructions are finalized, whereas in the past, the civil design institute had full autonomy.

CHALLENGES IN THE CIVIL DESIGN PROCESS

In recent years, there has been a growing trend for projects to involve international collaboration. For instance, a government project in the Middle East may engage a design consultancy from the U.K., working with a general contractor employing local people. At the same time, the equipment or components used may be from Continental Europe. This calls for an efficient global collaboration model that enables flexible design adjustments, for example, BIM, which is gaining popularity.

One of the factors that accompanies China’s rapid development is the adoption of a “three parallels” practice, where the three processes of design, construction and modifications in design are operated in parallel; and even before completion of the design, the construction phase is initiated. This is caused by rushing the construction of infrastructure. The fact is, sometimes even the project owners do not have a clear idea how the final product will look until they see the physical project beginning to take shape, after which they may wish to modify the original design.

Sometimes, the civil design institute can only design the foundation at its beginning stage, because the project owner has no clear idea what he really wants. This means that projects are often suspended at the design stage. It can be difficult and time-intensive to align the owner's intentions and the design itself.

Back in the 1990s, the civil design institute had more control over every detail, across all their construction projects. Now, in contrast, they have no authority over what downstream processes should be or how they should be initiated. Today, all their designs need to be approved and last-minute modifications in design are not uncommon during construction. This means it is difficult to predict the quality of work and when the projects will be implemented and completed.

Another challenge facing the civil design and municipal construction industry is the prevalence of on-site construction. In the past, contractors used on-site construction methods quite extensively. This had numerous drawbacks.

First, it was difficult to control material waste, because substantial construction waste was produced at the site and disposal was an issue. Second, it was hard to manage cost, because a lot of uncertainties can occur during construction on-site. Third, as more construction procedures took place on-site, it was much more difficult to manage the schedule. And last, as most of the construction took place on-site, much more space was being utilized than if prefabrication construction was practiced. This meant that surrounding roads were often blocked for extended periods causing traffic jams.

These problems can be addressed in several ways. The civil design institute could fully integrate a system of engineering, procurement and construction (EPC). They might utilize prefabrication whenever possible, for example prefabricating the reinforced concrete components and assembling them on site. Another method is to employ BIM technology, so that different professionals can work with the same model and have information transfer at different stages through a unified format, thereby significantly enhancing overall efficiency.

ADOPTING BIM – BENEFITS, CHALLENGES, SOLUTIONS

The two major benefits of launching BIM are – it enables 3D collaborative design and it facilitates communication by using a standardized format for data. Despite these benefits, there are challenges in adopting BIM. One major obstacle is that it involves changing people's habits, often needing to overcome a significant degree of resistance. When new ways of working are proposed within a corporation, this can result in internal clashes or even paralysis while processes are reconfigured. Bottlenecks can also occur while designs are being refined and assessed.

Often there are risks in project cycle costs as well. While operating in a planned economy, project's ROI was calculated very accurately. The government controlled the resources, including labor and transport costs, such as the costs of purchasing construction vehicles. As everything was thoroughly planned, the project owner had complete control of the costs. Now, within the market-driven economy, design has been reduced to only one stage – a single piece in the jigsaw puzzle subject to a number of cost variables. Likewise, the construction stage will have its own cost variables.

In summary there are four key factors coming into play – project cost, quality of work, scheduling and cost control.

The civil design institute should carry out cost control in four stages:

1. Do an initial estimate with the understanding that they do not yet have a precise grasp of the entire project.
2. Write or agree upon a project brief in advance of starting the design work. The brief will include the size, shape and appearance of the final product to further aid cost discussions.
3. Prior to starting construction, a firmer budget will be submitted.
4. A final cost calculation will be put forward upon completion of the project.

One of the benefits of using BIM is that it can maximize a budget by providing precise calculations of materials and construction costs. In general, a project has two kinds of costs – design and construction, as well as operation costs. Normally, design and construction costs account for 20 percent of the overall cost, while operation costs take up 80 percent. One-quarter of the design and construction costs (that is, 5 percent of the total project cost) is for design. So it is crucial that the civil design institute has a powerful, yet economical design capability and BIM meets this requirement.

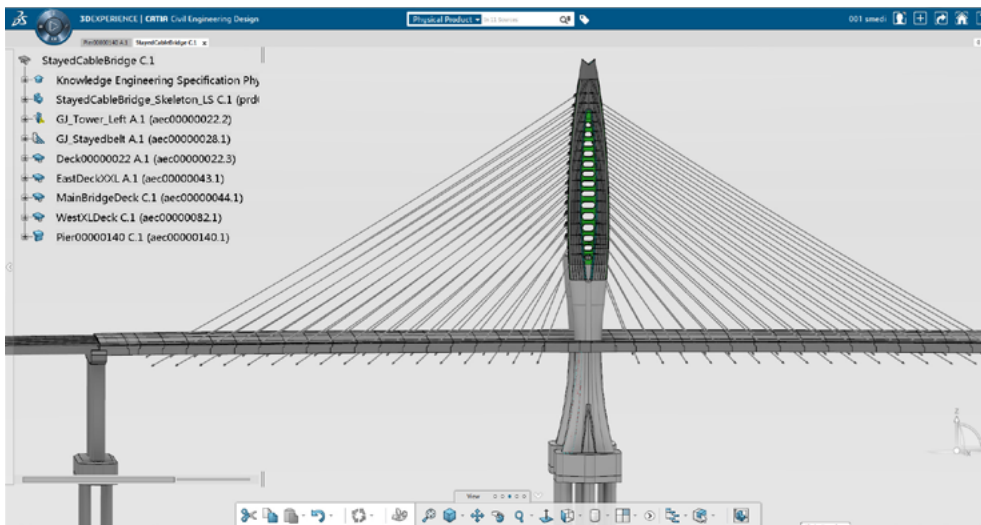
Introducing 3D Software and BIM

Since 2005, the civil engineering industry in China has been using Computer Aided Design (CAD) software to produce 3D design for advanced projects. Prior to 2005, the civil design institute used 2D design only and these drawings were not interlinked. This meant that changing one design sheet would not automatically trigger changes on related sheets. In 3D design, the designer can ensure that all changes are carried throughout the entire building plan, further enhancing accuracy throughout the project.

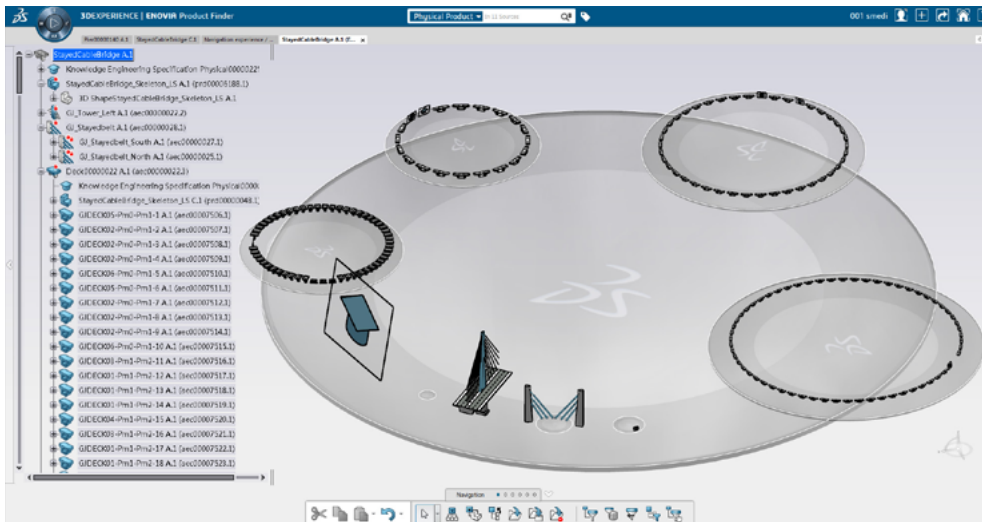
Traditional BIM software is developed for buildings, not for civil projects like roads, bridges and tunnels. Thus, they do not match the capacity of the civil engineering design module that was co-developed by SMEDI and Dassault Systèmes to visualize civil projects. The Dassault Systèmes **3DEXPERIENCE®** platform, can not only demonstrate design concepts, but it helps ensure a greater level of detail with increased precision for each project. Extensive BIM capability is required to illustrate entire projects with exact levels of detail shown within the prefabrication drawings offered by the **3DEXPERIENCE** platform, the leading software in this market.

CASE STUDIES

Ganjiang Second Bridge



SMEDI is particularly strong in designing bridges. Actually, the Institute designed almost all the major bridges in Shanghai. Of course, SMEDI's work goes way beyond the city of Shanghai. One notable example is the Ganjiang Second Bridge in Jiangxi Province, which has a "fish-like" design that fits very well within the surrounding landscape. The complex structure of the bridge comprises of a steel upper part, a concrete lower structure and in the middle, a mixed concrete and steel section. BIM enabled a clear division of work for the different engineers and their respective components.

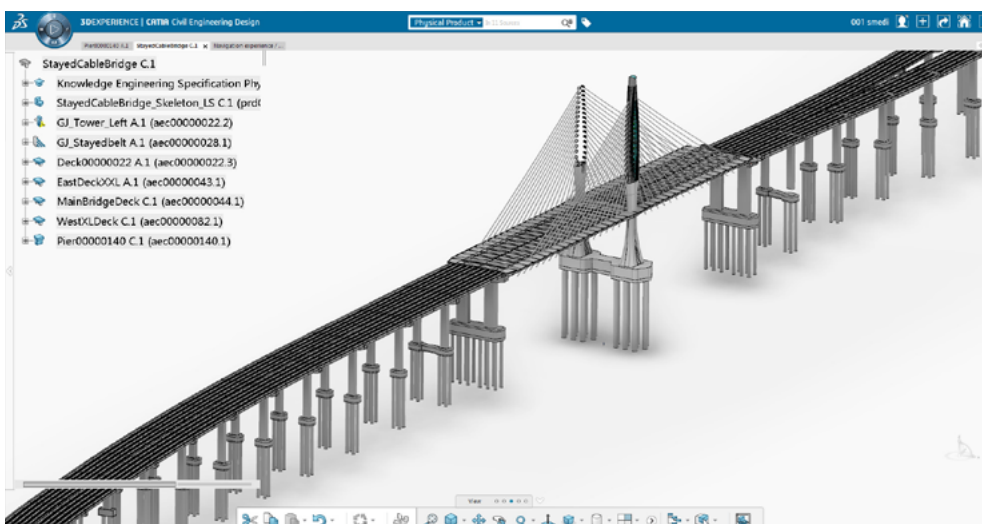


The design work for the bridge was led by SMEDI, with engineers from different disciplines collaborating. The project manager was a senior civil design engineer. A dedicated engineer designed the skeleton, determining the framework of the entire bridge. Another specialist engineer focused on the steel structure, while a further designer concentrated on creating a library of components for the various distinct features in the bridge.

SMEDI's collaborative design process meant that they clearly defined and divided the work involved, coordinated the roles and tasks and seamlessly managed the entire project.

In the conceptual design stage, the software allows designers to quickly create complex curves as skeleton lines and even supports using digital sketch tablets. With the skeleton lines created, the component library is crucial to the success of the project. The components (like piers, beams, columns, etc.) are intelligent, rule-based parametric objects and well-categorized in the library. The designers can select desired components from the library and put them on the skeleton lines and then the components adjust their sizes automatically to fit the skeleton lines and generate the BIM model in a well-coordinated manner. If designers change skeleton lines, it drives all components to update along with it, thus greatly saving modification time.

The SMEDI solutions can be animated to better showcase the proposed design concept, making them more functional than the static 3D visualization drawings which were produced previously.



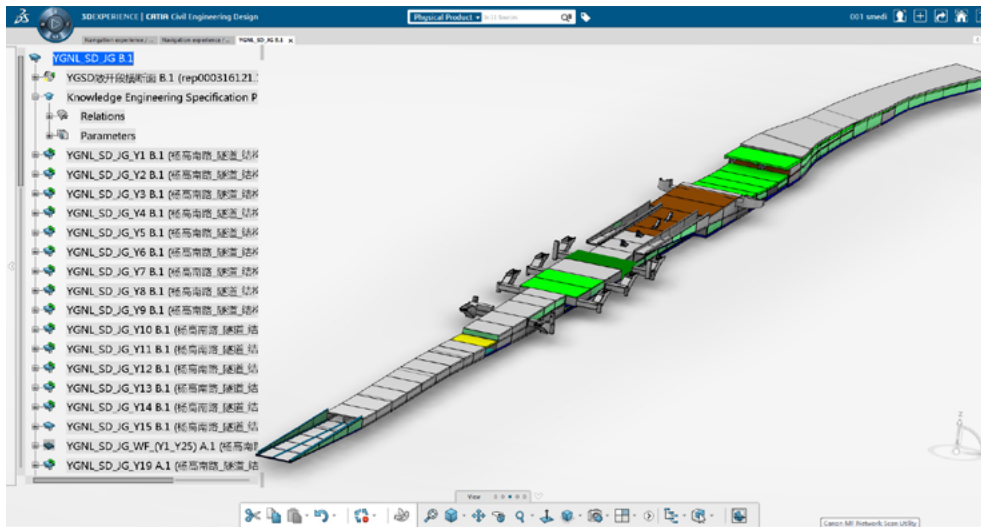
During the design of construction drawing stage, the software can check for conflicting production directions, as well as design errors. Users input measurements into the software to conduct analysis and optimize the build. These additional safety checks are of paramount importance for bridge design and construction.

Indeed this software helped make it much easier for SMEDI to make changes to the design, which can be very frequent and even at the last minute. In the past, making design changes could sometimes take even longer than the original design stage itself.

Yanggao South Road Tunnel

Another notable example is the Yanggao South Road Tunnel in Shanghai.

The reconstruction of the Yanggao South Road(Century Highway-Pujian Road) covers the area between the current Century Highway and the Pujian Road cross-route bridge, and measures a total of 1.95km (1.2 mi).The road, tunnel structure, bridge(Zhangjiabin Bridge),rain sewage pipeline, traffic sign and lines, signal lights, ventilation, monitoring system, power transmission and distribution, architecture, greening, and related equipment, as well as the initial greening and pipeline relocation, cost RMB1.455 billion in construction and installation, with the total investment amounting to RMB2.47 billion.

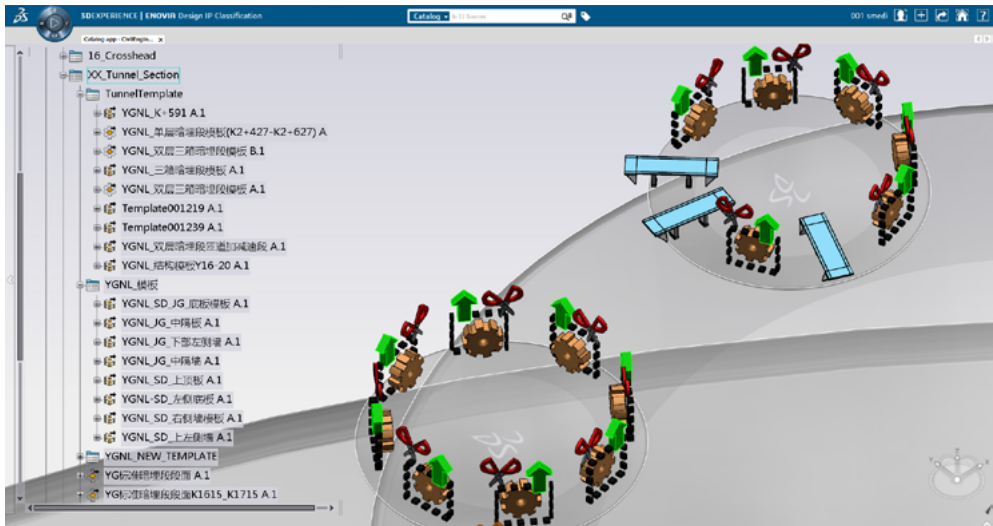


This project employs Dassault Systèmes **3DEXPERIENCE** platform version R2015x as the BIM production platform for the entire process. Compared with other software platforms, the **3DEXPERIENCE** platform has the following advantages:

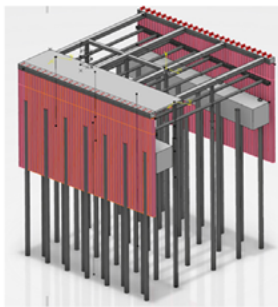
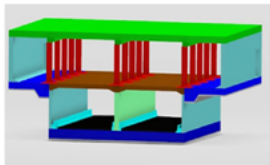
1. The platform adopts the Cloud platform and the structure model of the central server to unify the database of the project. This provides reliable data security protection for the corporate project.
2. The platform supports the type expansion of the BIM model and adopts the approach of self-defined uniform type in the Yanggao South Road Project. The side-stones, parapet and asphalt in the tunnel structure are laid out in a unified manner. This gave great convenience to the latter-stage quantitative surveying and simulated implementation.



3. With the multi-disciplinary, real-time-coordinated BIM platform, the design professionals in the structure, bridge and pipeline fields can carry out real-time design work on the same platform. This synchronized modeling function can instantly identify any errors in the design process and quickly check for any mutual interference between different models.
4. The BIM modeling workflow approach on the 3DS platform has been initially formed. The current software format can support a large-scale data model for a100km roadway. The entire BIM area covers the initial solution design, the intermediate detailed structure design, the latter-stage implementation simulation, project reporting and the online browsing based on Microsoft® Explorer.
5. The innovative re-use function of the knowledge template library can, with the template function provided by CATIA®, rapidly exemplify the different components in the tunnel structure, thereby avoiding duplication in modeling and enhancing working efficiency.



In the demonstration and proofing stage of the project solutions, the BIM technology was introduced to visualize the three-dimensional design, to compare the various solutions, and to optimize them. Satisfactory results were achieved in the briefing sessions for government leaders and the project owners. In the design stage, both BIM and regular design methods were employed, and the design results were checked to help ensure that the quality of the design drawings was secured. In the tendering stage for the construction, the joint design team made a significant breakthrough in estimating quantities of building materials based on BIM, and successfully acquired from the BIM information the quantities of concrete and steel for the main structure, and those used to protect the structure. 65 percent of the estimate was checked against the traditional calculations, and was used in the checklist for the formal tendering of the project.



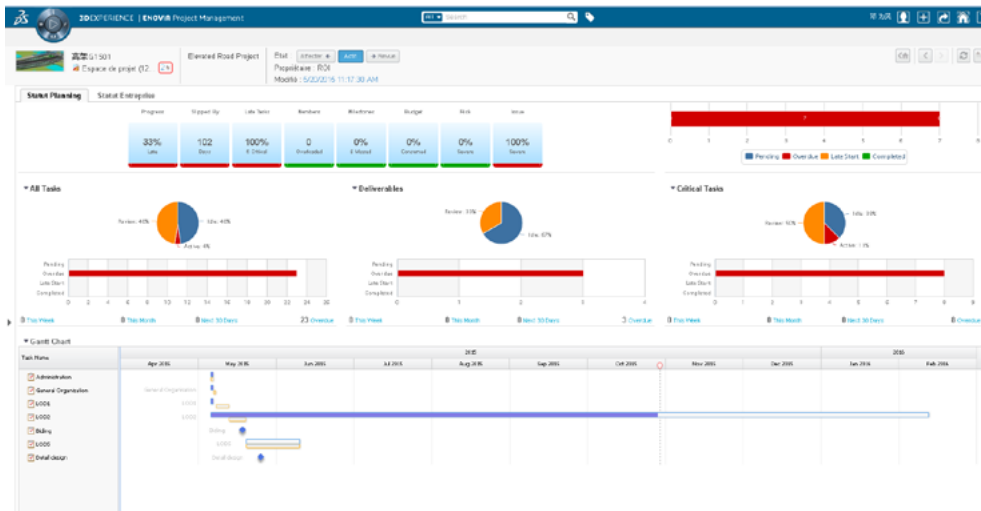
序号	名称	体积 (m³)	面积 (m²)	诱导缝长度 (m)	纵向施工缝 (m)	防水层面积 (m²)
1	YGNL_SD_TC_Y23_SE001	1516.2431	1742.4265	46.6	0	1612.8246
2	YGNL_SD_TC_Y23_ZS001	668.1697	1006.5624	28	0	0
3	YGNL_SD_TC_Y23_DE01	1310.42	0	30.6	0	1008.0153
4	YGNL_SD_TC_Y23_DE02	362.1655	0	6.3	0	245.3154
5	YGNL_SD_TC_Y23_DE03	362.1655	0	6.3	0	245.3154
6	YGNL_SD_TC_Y23_CQ01	93.1049	192.8603	5.11	1	183.9598
7	YGNL_SD_TC_Y23_MQ01	186.2098	385.7206	5.51	2	0
8	YGNL_SD_TC_Y23_CQ02	93.1049	192.8603	5.11	1	183.9598
9	YGNL_SD_TC_Y23_CQ03	203.0397	258.4174	6	1.8	215.9997
10	YGNL_SD_TC_Y23_CQ04	203.0397	258.4174	6	1.8	215.9997
11	YGNL_SD_TC_Y23_CS02	16.5418	0	0	0	0
12	YGNL_SD_TC_Y23_CS03	16.5418	0	0	0	0
13	YGNL_SD_TC_Y23_CS01	25.2673	0	0	0	0
14	YGNL_SD_TC_Y23_CS04	25.2673	0	0	0	0
15	YGNL_SD_TC_Y23_DC01	328.5297	0	0	0	0
16	YGNL_SD_TC_Y23_LQ01	222.345	810.1087	0	0	0
17	YGNL_SD_TC_Y23_ZZ01	97.95	0	0	0	0

序号	名称	长度/厚度 (m)	截面尺寸/型号	体积 (m³)	面积 (m²)
1	灌注桩	1521.7624	Φ800	0	0
2	围堰	0		129.6	245.7192
3	地下连续墙	1		1534.41	0
4	搅拌桩	0	Φ850	0	0
5	搅拌桩加固	108.0848	4000X1000	0	0
6	工法桩	0		599.2274	0
7	插拔桩	396	700x300x13x2	0	0
8	混凝土支撑	0		143.328	537.48
9	钢支撑	756	Φ609X16	0	0
10	钢支撑围檩	0	30X300X12X	0	0
11	混凝土系梁	0		49.68	248.439
12	钢连系梁	252.0012	XXX	0	0
13	钢围檩柱	271.299	XXX	0	0
14	栈桥	0		152.0506	0

HOW CIVIL DESIGN FOR FABRICATION VALUE HELPS CIVIL AND INFRASTRUCTURE PROJECTS

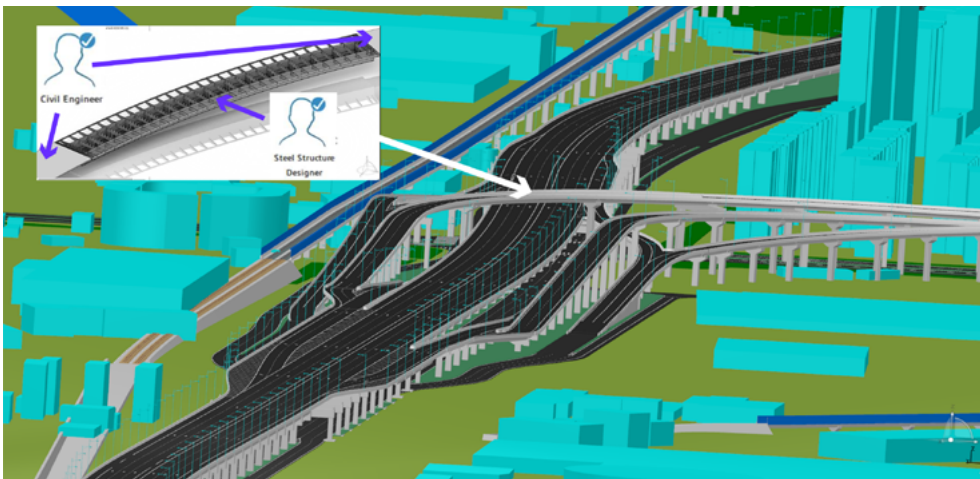
Integrated BIM Design Platform

The Dassault Systèmes Civil Design for Fabrication Industry Solution Experience powered by the collaborative **3DEXPERIENCE** platform enables simultaneous real-time access to design models and project data from anywhere and across different disciplines. This creates an interactive community of owners, engineers and civil designers who can work in parallel, share data and build quality and efficiency into every project. Civil Design for Fabrication provides a single source of truth with real-time management of the large amounts of information from various BIM environments, with IFC and OmniClass fluency. Users can start design from a catalog and make updates that are immediately reflected across all design models.



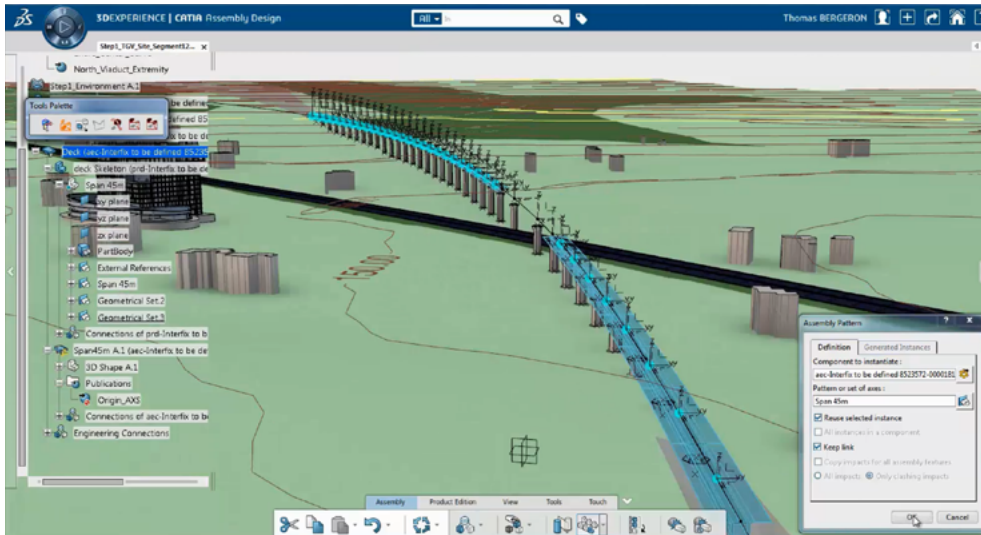
Collaborative Design

Simultaneous real-time access to design models and project data from anywhere and across different disciplines is made possible with the **3DEXPERIENCE** platform. No user is isolated. Customers can import data from any number of platforms to create a single-source mock-up where all parties — owners, designers, engineers and fabricators — can work together as part of an integrated design community.



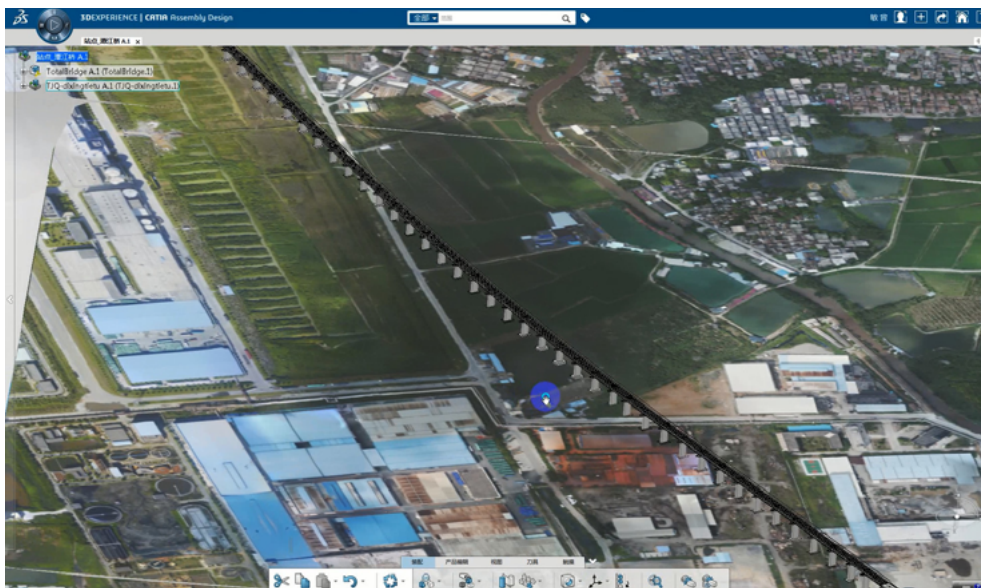
Flexible Design Change

The ability to work with existing 3D templates from the civil engineering catalog, or create your own original templates for future use, makes working with Civil Design for Fabrication not only highly customizable, but easily repeatable. Customers can save time by importing prototypes from a list of available components, using already established parameters and then easily modifying them. Modifications made to any template piece during design will be instantly updated throughout the model, ensuring consistency while reducing errors. This capability helps customers reduce time and effort updating and modifying 3D models.

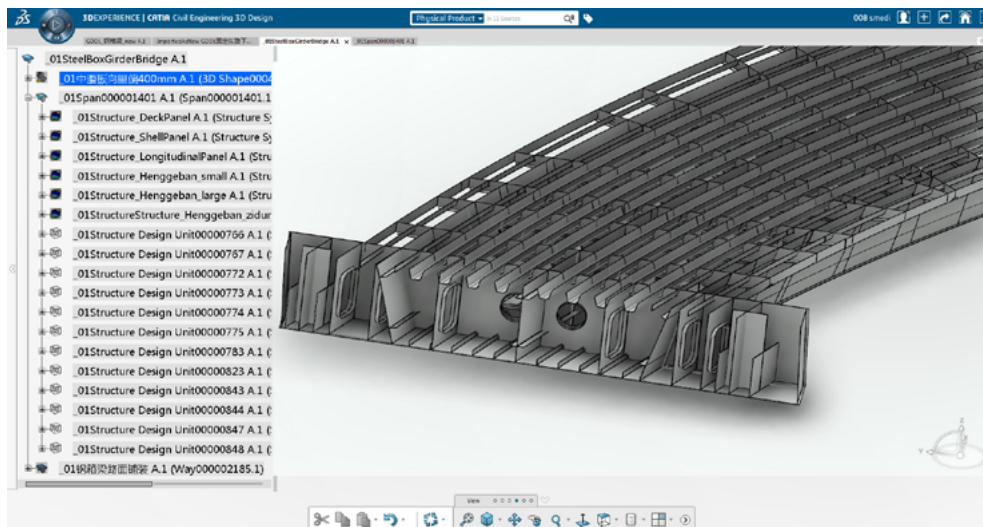


Large Model Handling

The platform integrates all design data including large BIM data, such as “true terrain” information. Using new geo location tools, users can bring precise site data into the model, or accurately prepare a site for excavation. CATIA apps on the **3DEXPERIENCE** platform provide extended data handling capability up to 200km. Virtual modifications to any terrain automatically lead to relevant excavation calculations. Coordinates and terrain information can be extracted to use in the model, or design information can be placed in a true map to provide an accurate site overview and visual context for all users.



Civil Design for Fabrication connects conceptual design models to fabrication data, as well as to construction costs, quantities, specifications and schedule. It enables customers to generate prefabrication models from the integrated BIM master data. The integrated design processes reduce rework and waste and improve design process efficiency.



Civil Design for Fabrication Industry Solution Experience, powered by the **3DEXPERIENCE** platform, makes it much easier to accommodate changes in design, which can be very frequent. Changes are inevitable, as unforeseen factors often emerge during construction. Quite often making changes takes even longer than the original design stages and in the past, this could be a very painful process.

Furthermore, Civil Design for Fabrication has saved a very significant amount of the overall construction time for a project of this nature. It is commonly agreed that designers spend one-third of their time doing design work and two-thirds communicating that design. Apart from facilitating the design work, BIM makes communication and collaboration much faster and easier and this translates into substantial cost savings.

SMEDI made their custom BIM platform by working with Dassault Systèmes to solve their civil design industry challenges. Overall, the Dassault Systèmes **3DEXPERIENCE** platform is both reliable and innovative and effectively drives large-scale industrialization.



Dassault Systèmes, the **3DEXPERIENCE®** Company, provides business and people with virtual universes to imagine sustainable innovations. Its world-leading solutions transform the way products are designed, produced, and supported. Dassault Systèmes' collaborative solutions foster social innovation, expanding possibilities for the virtual world to improve the real world. The group brings value to over 190,000 customers of all sizes in all industries in more than 140 countries. For more information, visit www.3ds.com.



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Americas
Dassault Systèmes
175 Wyman Street
Waltham, Massachusetts
02451-1223
USA

Europe/Middle East/Africa
Dassault Systèmes
10, rue Marcel Dassault
CS 40501
78946 Vélizy-Villacoublay Cedex
France

Asia-Pacific
Dassault Systèmes K.K.
ThinkPark Tower
2-1-1 Osaki, Shinagawa-ku,
Tokyo 141-6020
Japan