Indian Institution of Bridge Engineers

E-Bulletin

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Indian Institution of Bridge Engineers **(IIBE)**
was founded by **Er. M.C. Bhide,**
In the year **1989**
with Head Quarters in
Mumbai.
MISSION
Bridging the Gaps -
Inter-Continent
&
Intra-Continent

Table of Content

About IIBE

Since last 34 Years, IIBE is catering to the Bridge Engineers by Providing an Exclusive Forum to Exchange Ideas and knowledge of Bridge Engineering.

Engineering is considered as one part of larger topic of roads and Highways, but Indian Institution of Bridge Engineers aims at providing a platform to Bridge Engineers for dissemination of knowledge / new developments in Bridge Engineering.

I.I.B.E is proud that so far it has published more than 29,200 pages of Technical Literature including this Conference Documentation. I.I.B.E's work and unique role as a professional body in the sphere of Bridge Engineering has been greatly appreciated and applauded not only all over India but the large number of countries in the world.

Message From **Director General**

Greetings and best wishes to fellow Bridge Engineers !!!

We are witnessing one more great event in the upward march of the IIBE today. The restart of the periodic journal. It is a testimony to the enthusiasm and hard work of the IIBE team at the headquarters.

This reappearance of the periodical fulfills a long standing demand of many members of the IIBE. I congratulate all those who have put in much hard work to make it a reality.

The Bridge 2022 was a great event which I was fortunate to witness in person. The attendance there speaks for the hunger for such events. Many good , interesting papers and presentations were witnessed there. It is very satisfying to note that several of those papers / presentations are included in this first of the rejuvenated periodical. I am sure they will be received avidly by IIBE members.

Bringing out a periodical regularly requires very great dedication and hard work. Doing it in additions to one's regular busy professional work is all the more commendable. I am full of admiration for the team and wish them success.

Er. SR Tambe
Director General, IIBE

I offer greetings and best wishes too all the IIBE members and to this periodical !!!

Message From **President**

"Covid-19 is almost over' which has been proven by successfully holding IIBE's in-person event BRIDGE 2022 in Pune. My hearty thanks to IIBE - Pune centre for organising this mega event in December 2022! The other encouraging thing is that IIBE-Hyderabad centre has agreed to organise BRIDGE 2023 on 23rd & 24th June 2023 in Hyderabad. At this juncture I take pleasure in informing you that the mega event of this magnitude was started in the year 2018 with BRIDGE 2018 in Lucknow, followed by BRIDGE 2019 in Patna. BRIDGE 2020 & BRIDGE 2021 were held through virtual mode.

Er.Vinay Gupta
President, IIBE

As we say, it's never too late, we are restarting the old trend of IIBE periodic journal. It will be in the form of an electronic form. At present we plan to release two such e-journals per year.

This issue of IIBE Journal includes several interesting papers on various important topics dealing with matters pertaining, directly or indirectly, to bridges & their components. Since, very interesting deliberations were made during BRIDGE 2022, our secretariat contacted the presenters for their complete papers or extended abstracts.

I remain indebted to the presenters for taking the time out from their busy schedules and our Technical Coordinator, Ms Deepika Singh for putting things together for the journal. The readers are expected to immensely benefit by reading this journal, especially the ones who could not physically attend the event in Pune.

Good Luck to All ...!!!

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Structural Retrofitting of Chitpore Bridge: Case Study

By Dr M.V. Joshi[1], Vivek S V[2], J. D. Bhanushali[3]

INTRODUCTION

Bridges have been important structures from ancient times as they play vital role in the socioeconomic growth of individuals as well as the country. The chitpore bridge is one such example that contributed in the growth of Kolkata city from as early as 1843. The chitpore bridge was constructed under the leadership of John Thomson, who was the Superintendent of canals and Agent for Iron suspension bridges. The bridge spans 99 feet and has a roadway that is 24 metres wide. It was popularly referred to as the Bagbazar Bridge. It is one of the earliest examples of the bowstring bridge (refer Fig. 1). Deterioration is a common problem in bridges and Chitpore Bridge is no exception.

Fig. 1 Chitpore bridge

KMDA conducted structural inspection of Chitpore Bridge

The Kolkata Metropolitan Development Authority KMDA, conducted structural inspections of several bridges in Kolkata and came to a realization that Chitpore bridge falls under the category of "vulnerable bridges and flyovers". It needed immediate repair and restoration to avert any major mishap in the near future.

[1] PhD IIT Bombay, CEO of SSSPL,[2] M-Tech IIT Kharagpur, [3] MSc in Civil Engineering IIT Tirupati

Non- Destructive Tests Performed in Chitpore Bridge

In August 2019, LASA was awarded consultancy services for Chitpore Bridge. The condition of the bridge was soon surveyed and non-destructive tests were performed. The seemingly healthy bridge revealed active corrosion in selected areas. NDT test revealed that;

- In the vertical hangers, steel reinforcement has lost its diameter at several locations
- Spalled portions and discontinuous rebars were visible in hanger columns, under the deck slab and on cross beams (refer Fig. 2)
- The structural strength of sectional members was compromised by corrosion
- Pitting corrosion of the embedded steel in the vertical hangers and in the beams supporting the deck

Fig. 2 Spalled portions show exposed and discontinuous rebars in hanger columns, under deck slab and on cross beams

Adding to its already distressed condition, nearby Tala Bridge was closed down, sending substantial traffic to Chitpore Bridge. To prevent a catastrophe, an immediate strengthening of the structural system was necessary. It had to be done fast with due diligence. That's when Sanrachana came to the rescue.

REPAIR AND RETROFITTING OF CHITPORE BRIDGE EXECUTED BY SANRACHANA

Sanrachana is one of the pioneers in the area of structural retrofitting & protection in India and has decades of experience in executing bridge repairs across the country. It has served clients on over 2000 projects involving commercial properties, industrial facilities, energy plants and public infrastructure of varying scale.

Overview of work executed:

- Sandblasting, anti-corrosion treatment
- Providing additional rebars, micro-concreting
- Strengthening of hangers, deck & cross beams with SRM carbon laminates & SRM C-wraps
- Post-tensioning 4 Mac-alloy bars with 5 tons each, to counteract tension on each hanger

The team started repair work with sandblasting in Chitpore to get clarity on underlying distressed concrete. Delamination and spalling were detected and removed with a hammer and chisel. The exposed rebars of the hangers were treated for corrosion. The section was rebuilt with highstrength micro concrete. The underside of the bridge was made accessible with platforms supported by a structural steel section.

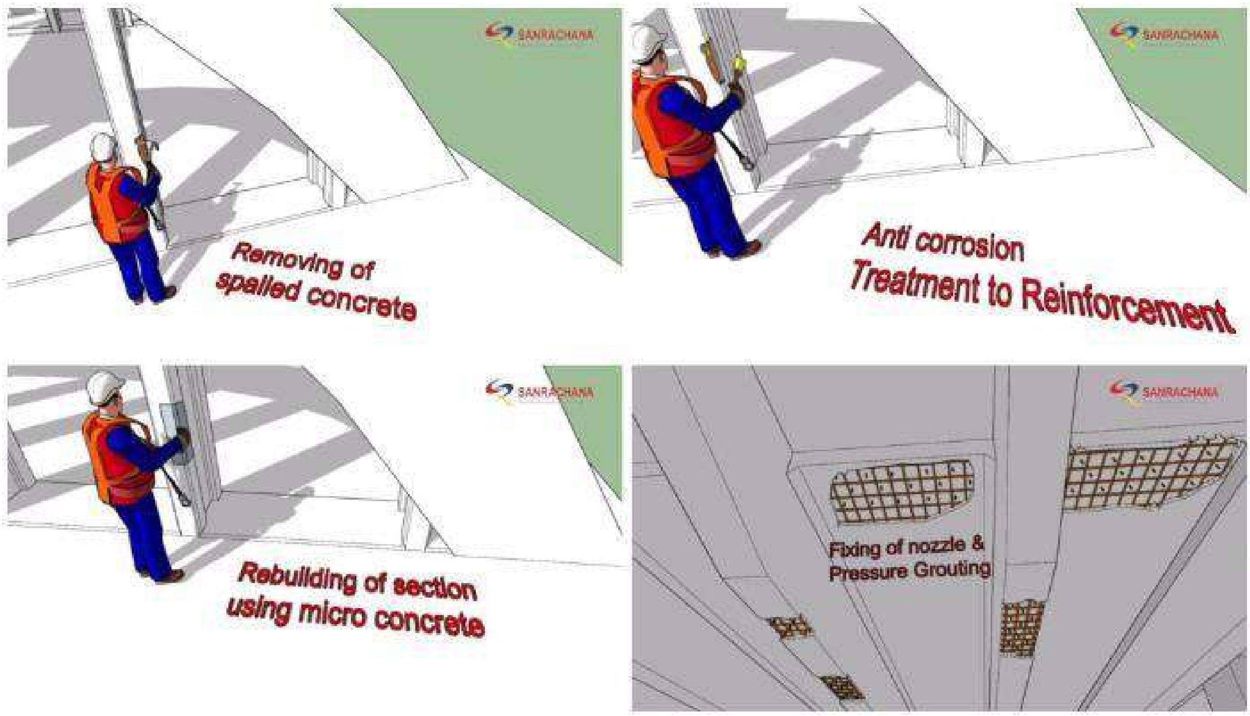

Fig.3 Illustration of repairing scheme for Chitpore Bridge

The strengthening of hangers, decks & cross beams was done with SRM C-Lam carbon laminates & SRM C-wraps as shown in Fig. 4.

Fig. 4 Application of SRM carbon laminates & SRM C-wraps

Fig. 5 Illustration of strengthening activities using MC Alloy Bars

The base of the hangers were armored with a 1.2m cover block. Structural steel sections were used on the top of hangers above the RCC arch. Connecting these, high-strength Mc-alloy threaded bars were installed. The tensioning mechanism was to be operated from the top of the hangers.

Mechanism of post-tensioning

Upon tightening the top nuts of the McAlloy bars, tension force gets developed in the bar, because of which a reaction force of compression is generated on the RCC hangers. Post tensioning in this manner keeps the concrete under compression while the McAlloy bars handle the tension. Typically while post tensioning, PT force is applied using hydraulic jacks. The advantage of using McAlloy bars is that PT force can be applied without any such machinery. The trained workforce of Sanrachana are seen applying PT force manually by using spanners, in Fig. 6.

Fig. 6: PT application on MC Alloy bars

With the application of protective coating, the work was completed. All the contract criteria were met by Sanrachana.

SUMMARY AND CONCLUSIONS

The chitpore bridge was repaired using anti corrosive treatment, rebuilding of concrete section with micro concrete and polymer followed by strengthening using SRM C-wraps and SRM CLaminates of carbon fiber. After Successful completion of repairing and strengthening work, the bridge was open to use for public.

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Structural Integrity Assessment of Submerged Bridges using Robotic Inspection and Scour Survey

By Ashish Antony Jacob, Vineet Upadhyay, Shanmukha Kavya V, Tanuj Jhunjhunwala

INTRODUCTION

In a developing country like India, road and rail bridges are some of the most important infrastructure assets that connects every corner of the country. These assets tend to undergo wear and tear with aging. When these assets are submerged, they are susceptible to further damages such as scouring, rebar exposure, corrosion, cavities etc. Hence, periodic inspection of bridges is essential to detect early deterioration and to schedule maintenance and restoration plans to prolong their life, prevent catastrophic damages and loss of lives. Typically, inspection procedures that are used conventionally are limited to areas of the structures which are easily accessible and safe to work. These inspections which are majorly carried out by human divers come with several limitations such as depth that can be covered by the diver, accuracy, endurance, safety etc.

In this paper, an advanced structural assessment of submerged portions of the bridge is discussed, which covers all the limitations posed by alternate methods. Planys Technologies, a young start-up with indigenously developed state-of-the-art technology for robotic marine inspection (using Remotely Operated Vehicles (ROVs)), has carried out over 170 bridge inspections across the country and come with seasoned experience in multiple bridge inspection applications such as visual inspection, corrosion monitoring, concrete structural integrity assessments, digital reporting and so on.

The remotely operated vehicle (ROV) can be controlled from a safe location and offers numerous advantages including unlimited endurance, enhanced visual inspection in turbid waters, improved system for data acquisition and repeatability. The paper describes a comprehensive structural integrity assessment that Planys has tried and tested on the submerged regions of the bridge. Further a case-study is also presented that highlights the work done by Planys team on a live project.

India has faced several bridge failures in the past such as the collapse of a foot over bridge in Mumbai, 2019, and the most recent bridge collapse in Gujarat in 2022. A recent analysis of the bridge failures in the country between 1977 to 2017 shows over 2130 bridge collapses.

All these bridge failures lead to heavy toll on life and property [1]-[4]. Maintaining safety and reliability of ageing civil infrastructure, operating for several decades, is of key importance to prevent catastrophic failures, especially after design lifetime is over and during natural disasters.

Standardized inspections at regular intervals have shown to identify defects at their initial developmental stages, therefore significantly reducing the overall repair and maintenance costs.

CURRENT TECHNOLOGY FOR BRIDGE INSPECTIONS

Visual inspection is the first step in the evaluation of safety and reliability of assets. Key stages in the process of structural deterioration of concrete structures that may be identified by visual inspection include cracking, seepage, spalling, moisture ingress, beam delamination, exposed and corroding reinforcement [5] and subsequently, maintenance actions can be planned. However, visual modality of inspection is dependent on the expertise and knowledge of the investigator and it is ineffective when used alone, as it presents superficial structural information. [7]. In order to obtain in-depth structural integrity information quantitative NDT techniques such as electromagnetic, acoustic and ultrasonic methods are preferred.

Ultrasonic pulse velocity (UPV) technique is among the most widely used inspection method for concrete structures owing to its portability and ease of applicability. The technique relies on the measurement of time of arrival of ultrasonic waves, T, traversing through the material of interest to calculate the pulse velocity, V, which is typically in turn correlated to the quality of the concrete. The pulse velocity is influenced in varying magnitudes by numerous factors including aggregate size, cement properties, reinforcements, member size, moisture, and member stress. Therefore, the UPV method can serve well as an indicator to identify zones of non-uniformity and as a prelude to advanced NDT investigation [8]. This technology is available in the market for superstructure structural assessments. For the substructure and the submerged portions, Planys has developed the technology indigenously and has successfully used it on projects to assess the structure integrity of submerged portions of concrete structures.

Structural durability of the reinforcement is significantly compromised by corrosion. For relatively newly constructed concrete with defined composition and structure, reinforcing steel is well protected against corrosion. However, concrete surface pH decreases with time and allows the threat of contamination with external chemical components that can penetrate the concrete and reach the reinforcement and induce accelerated corrosion. All submerged assets have several portions of their substructure in marine conditions which leads to further corrosion upon exposure. The corrosion process can be delayed by the use of certain types of concrete surface protection or employing low absorption concrete [9]. Many parameters including chloride content, sulphate ions, and concrete pH need to be evaluated in order to obtain a clear assessment of structural integrity [10].

ROV BASED UNDERWATER INSPECTION APPLICATIONS

Planys technologies has developed several technologies for underwater NDT, visual inspection and other surveys that have many use cases and applications in bridge inspections. Some of them are listed hereunder:

- Visual Inspection to identify visual defects such as cracks, cavities, honeycombing etc
  - Submerged piers and abutments
  - Underdeck of the bridge
- Ultrasonic thickness gauging of the metal parts of the bridges if any
- Underwater Concrete NDT - Ultrasonic Pulse Velocity (UPV) for concrete structures

- Bathymetry and Side Scan Sonar Surveys
- Scour surveys using sophisticated SONAR technologies

BENEFITS OF ROV BASED INSPECTIONS

The submerged portions of such civil structures, i.e., its substructures, are conventionally inspected by divers carrying payloads including cameras and lights. Inspection by divers pose human safety risks owing to unpredictable flow velocity, poor visibility, presence of debris and entanglement. Turbid or murky water presents a key challenge, limiting conventional manned inspection surveys to clear waters. Further, conventional scuba diver-based operations are also limited by the maximum sustained time and working depth which are typically 20 minutes at 20 m depth, 15 minutes at 30 m depth and 10 minutes at 40 m depth (ref: guidelines railways).

This proposed methodology for underwater inspection and NDT has various advantages such as mentioned below:

a. The ability to inspect in dark and flooded areas,
b. Safe operations as human intervention underwater is nil
c. Unlimited endurance,
d. Enhanced stability,
e. Reliable data acquisition with repeatability
f. Lastly the AI enabled post-inspection analytical digital reporting dashboard (for autoidentification, quantification, enhancement and categorization of defects) also allows cross-comparison of inspection data recorded across multiple years and thus appropriately augments asset owners.

The results can aid the authorities rapidly make key decisions concerning repair, maintenance, and safety of the structure.

CASE STUDY:

Inspection of road bridges in Maharashtra adapting the ROVs based substructure inspection and scour survey using 3D imaging SONAR

Planys conducted several road bridge inspections in multiple districts across the state of Maharashtra including few iconic bridges of national importance. These bridges are located on prime routes linking several important locations of the district and hence of significant importance to the state. The scope of work that Planys executed for these bridges included both Visual inspection and scour survey of the submerged piers of the bridge.

ROV BASED INSPECTION OF SUBSTRUCTURES

ROVs [11] are unmanned robots that can be designed to reach target immersed narrow and restricted locations and perform immersed structural inspection in the form of visual and nondestructive evaluation, and assessment of water quality. Further, the operation of ROVs has fewer limitations in terms of depth of operation, communication, and endurance as compared to human divers. Apart from such advantages, ROVs offer the possibility of streaming live data back to the control station (along with end user and surveyor), operation in hazardous conditions and high-speed on-board or on-site data processing capability.

Planys Technologies brings cutting-edge technology to address industrial problems, providing underwater inspection and survey solutions using indigenously manufactured submersible remotely operated drones. Indigenously developed technology has been widely acclaimed and accepted in numerous sectors in India and abroad including power, oil and gas, offshore and freshwater domains. Planys has completed 285+ projects in underwater inspection including 170+ bridge inspections using Remotely Operated Vehicles (ROVs).

The typical setup of the ROV and its subsystems are shown in the in Figure 1. The power is supplied to the command module, through which, it is fed to the winch and then forwarded to the ROV. The command module and the tether winch are placed in a safe location above the bridge. The ROV is deployed through the top of the bridge or through a boat based on access points available at the site.

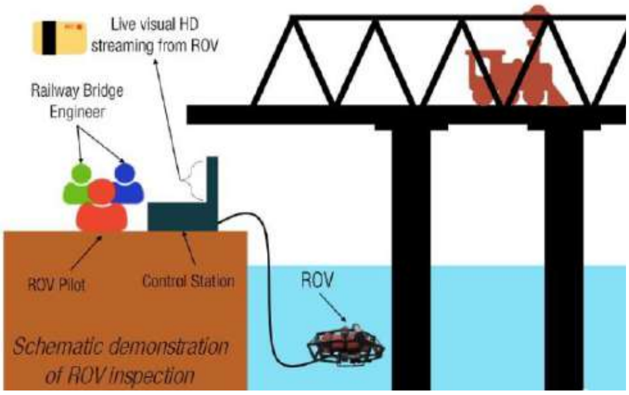
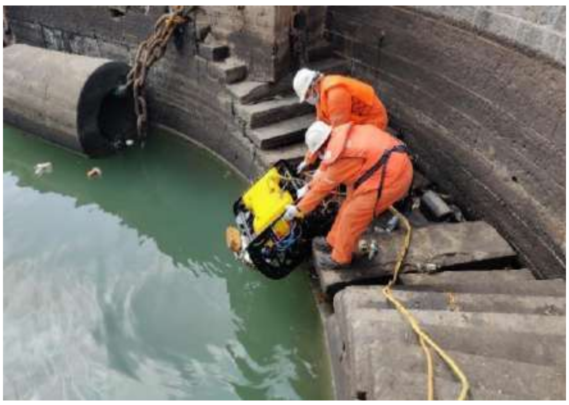
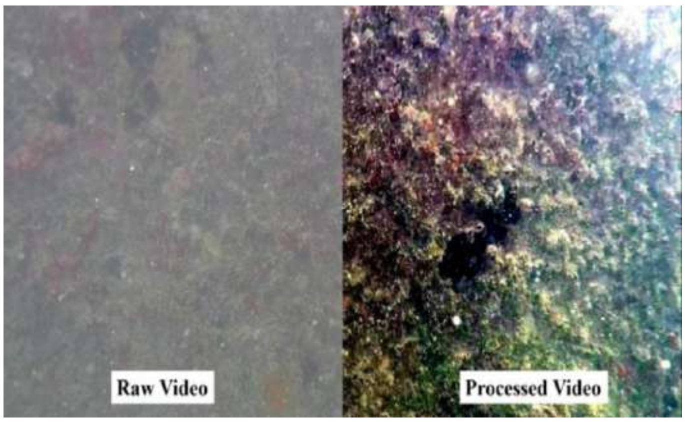


Figure 1: A schematic showing the overall setup for the ROV based Bridge Piers inspection

ROV is equipped with high-definition cameras delivering a resolution of 1080p with 60 frames per second, which is shown in Figure 2(a). Innovative technology to perform visual inspection even in extremely turbid water has been developed and used in inspection surveys. As shown in Figure 2(b), software-based video enhancement algorithms are used to compensate for quality loss in low light and turbid waters, such as to compensate loss of colour, contrast, or sharpness.



(a)



(b)

Figure 1 (a) a photograph showing the ROV ready to be deployed (b) sample results from the video enhancements, showing a typical raw video on the left and the enhanced video on the right

SCOUR ANALYSIS USING 3D IMAGING SONAR TECHNOLOGY

In extremely turbid (especially during monsoons) traditional underwater videography will not be possible to assess the orientation/spread age of scouring as the visibility is less than 10 cm. Underwater 3D Imaging Sonars, also known as acoustic cameras, are used to replace video cameras in such cases. These sonars not only work in zero visibility conditions, but they also offer measurement solutions. They can hence assess and identify scouring if any.

The sensor uses new high-resolution profiling SONAR technology to create an easy-to use underwater 3D Multibeam scanner. The sensor works much like a topographic laser scanner, using high frequency sound beams instead of lasers to create extremely detailed 3D imagery to collect measurement data with centimetre-level accuracy.

The 3D Imaging SONAR has a 360 deg spherical coverage as shown in the diagram. Its optimal range is 20m, as such, the subsequent scan will be taken within a 25-30m range of the current scan location to overlap data for creating an efficient mosaicking. Data obtained needs to be post-processed (data view is not real-time) and stitched to be made sense of using an OEM software. Post capture, 3D data requires playback, editing and post-processing, followed by mosaicking. Depending upon the site conditions, these processes can take up to several hours for each collected scan. Figure. 3 shows a mosaic created around one of the piers inspected and shows the different contour levels indicating scouring. The scour depth can also be measured by the technology to assess the severity of the damage.

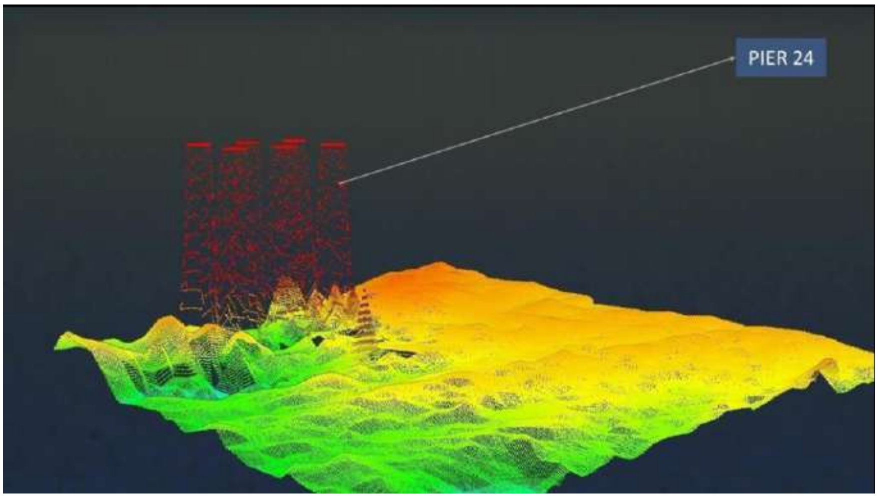


Figure 3 Illustration of the scouring seen around one of the piers in 3D Mosaic

RESULTS AND DISCUSSION ROV BASED INSPECTION OF THE SUBSTRUCTURES

Laser-based defect size estimation, metadata from the ROV including location, and depth at which the defect was observed, are overlaid onto the recorded live video feed. A sample defect image is given in Figure 4 showing three important features, 1. ROV twin lasers, 2. Size of the estimated defect, and 3. Position tagging of the defect on the bottom image. Custom designed underwater lights and camera system appended to the ROV's turbid water inspection module recorded the following sample defects, from various bridge substructures presented, in Figure 5. Major defects including cavities, honeycombing and cracks were observed with enhanced visibility using the ROV's turbid water inspection module.

This data overlay greatly enables localization as well as monitoring the growth of a defect and improves repeatability of results during a future operation; further, the feature can enable comparison and tracking of historical defect propagation status over a given period. Bright spots can be seen on the edges of the images given in Figure 5 (a) to (d). These are artefacts caused by total internal reflections within the turbid water inspection module.

Figure 4 A sample defect image captured by the ROV is overlaid with the defect depth and orientation, the ROV's twin laser and measured size of defect

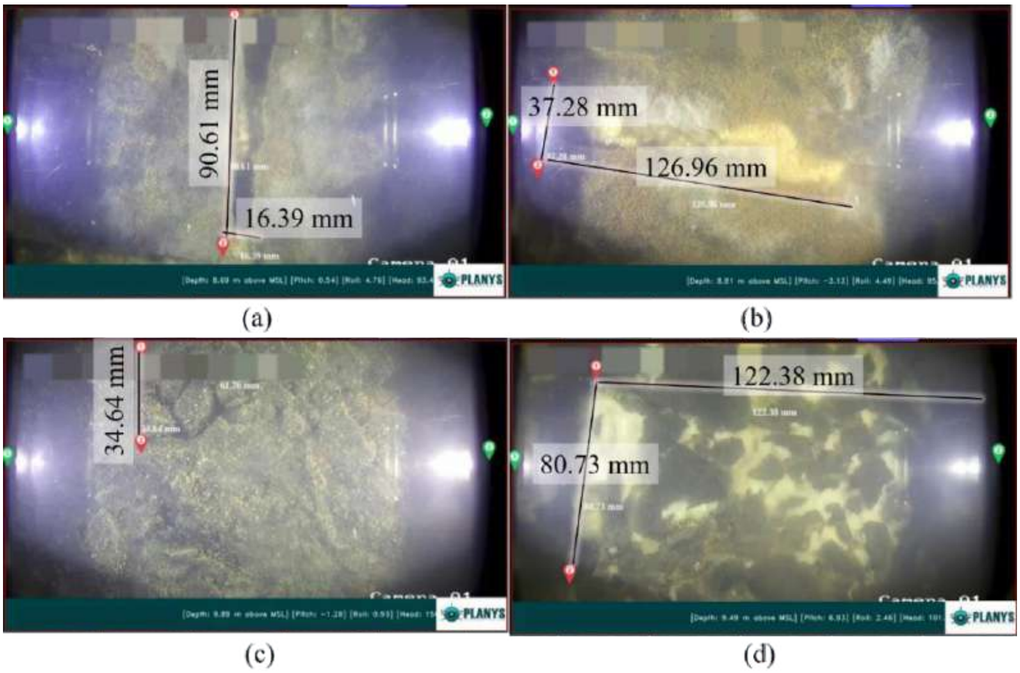


Figure 5 Defects observed during the ROV based inspection of the substructure using the turbid water inspection module showing major cavities, cracks, honeycombing and surface deformation, respectively observed at (a) 8.6 m, (b) 8.9 m, (c) 9.89 m and (d) 9.49 m from the reference level of the bridge pier, respectively; the measured distances of the defects are highlighted artificially for sake of clarity.

DATA PRESENTATION AND REPORTING

The importance of presentation and reporting of data and critical sections, respectively, is often overlooked in a conventional structural assessment survey. The onus is often left to the end-user to examine large volumes of data with just numbers or video files. Further, in the case of periodic inspection of an asset, conventional data presentation methodologies do not allow locating or track key defects which can otherwise improve the confidence of decisions made following an investigative survey. The resulting examination becomes erroneous and makes the process of making important decisions about repair or maintenance of the structure under inspection very slow and challenging.

Planys Analytics Dashboard™

Planys Analytics Dashboard™ (PAD) is an Intelligent AI-enabled Digital Analytics & Reporting Dashboard. It showcases compiled and analyzed data embedded into a highly interactive and user-friendly software interface depicting inspection locations with depth, position tagging, defects, key results and observations on a map. Further, AI-based analytics and enhancement tools extract meaningful insights and categorize them per industry standards. It is highly customizable and can integrate multiple assets on the same dashboard, making it very easy for high-level managers to take effective decisions.

Data collected at the bridge sites was further analyzed and presented on the Planys Analytics Dashboard. Data included videos from underwater visual inspection in turbid waters, underwater concrete UPV data points and complex SONAR data. All these results were tabulated and compiled on the user-friendly software interface depicting inspection locations, results and observations on a CAD model of the structure inspected. As a result, the dashboard reduced the interpretation time of the dam engineers by 95% and improved decision-making ability, and reduced costs by taking data-driven decisions for repair and maintenance.

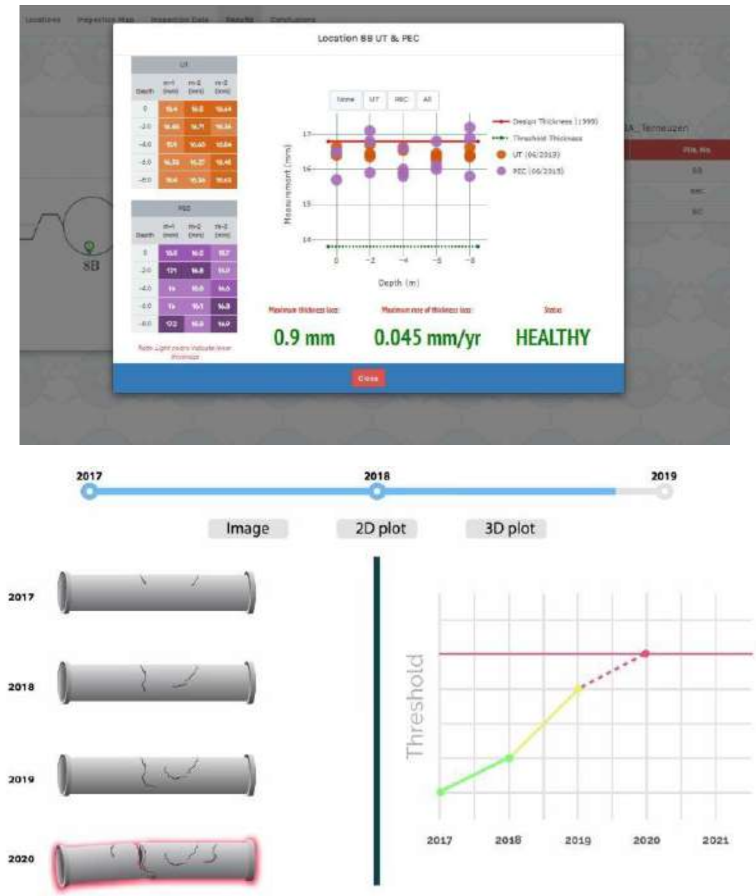


Figure 6 Snippets illustrating assessment dashboard compiling data recorded during the survey operation wherein (a) assessment of structural integrity is performed, and the overall condition of the sample substructure is determined, (b) defect characterization and tracking during successive periodic inspection surveys help to improve prediction of the remaining life or failures of the asset

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

The paper presents one of the new technologies used for integrity assessment of the submerged portions of the bridges. The studies are carried out by various road and railway bridge asset owners. A methodology of integrity assessment of large structures using an approach which combines multiple techniques for inspection of substructures using unmanned submersible robotic systems was also presented. Key applications and use cases of a remotely operated underwater vehicle (ROV) are presented which is possible due from the support of various sensors and tools for specific bridge health monitoring applications, including overall integrity assessment, sonar surveys, scour monitoring, and debris volume estimation. Defect images, overlaid with metadata to enhance defect growth tracking and data repeatability, were also presented for the robotic inspection survey for the submerged part of the bridge. Overall structural integrity of the bridge was assessed after consolidation of data from both methodologies of the survey. Numerous defects ranging from moderate to severe criticalities have been identified in substructures of the assets in the survey project presented. Further SONAR based scour assessment use case is also presented to understand different issues faced by bridges that is not obviously visible. This combined data is most useful in deciding the type and methodology of the repairs required for the bridge to enhance its serviceability, as well as extending the reduced life by strengthening measures based on accurate data where normal visual inspection of the underwater structure is not possible.

Further, a comprehensive model to predict remaining life of the asset accounting numerous factors affecting structural health such as temperature, rainfall, or chemical composition of water and soil is under development.

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Architectural System for Arch Bridges

Dextra India

Setting the Context

The architectural systems mainly includes - Tenison Rods & Compression Struts which is not just functionally effective but also aesthetically pleasing structure.

Featuring a wide range of sizes and accessories in various steel grades and in both carbon and stainless steel with various finishes, tension rods and compression struts meet the engineering and design requirements of consultants and architects alike.

Tension rods typically act as bracing or suspension elements and provide the benefits of high strength, length adjustability, ease of installation as well as the ability to be post-tensioned after installation.

Compression struts complement the range of architectural bar systems and are used when structural members are required to take compression loads as well as having the benefits of installation and aesthetic appeal associated with the tension rod system.

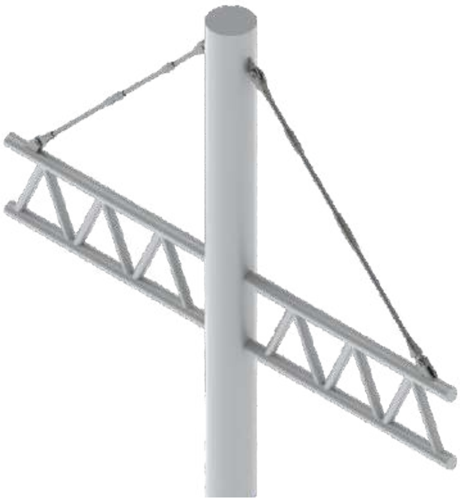
In additional to Arch Bridge & Pedestrian projects, following are the other applications of Architectural system –

1. Roof support systems
2. Hanging floors
3. Truss bracing systems &
4. Temporary stays & braces

- Product Feature & Standard Accessories

  - **Tension Rod – Carbon Steel**

Generally, Tension rods are available in high strength grades in CS, allowing the use of smaller diameters to achieve the same tension capacity as larger diameter mild steel tension bars. In situ length adjustment can be achieved by rotation of the bar into the



Forks and Spades		A pair of Fork and Spade form an articulation joint. Forks and spades are connected to gusset plates.
Couplers		Couplers are used to connect standard length bars to achieve a longer required length.
Turnbuckles		Turnbuckles are used to connect and adjust the bar to achieve the required length and remove sagging.
Cross Turnbuckles		Cross-turnbuckles allow two tendons to cross each other in the same plan.
Lock covers		Lock covers are used to cover the exposed thread of the bar.

forks and/or at each turnbuckle along the tendon. Turnbuckles also allow for the application of a preload, making for example self-weight sagging corrections easier.

Typical material grades are 460, 520 & 700 N/mm² & the thread diameter range from M16 to M133.

Tension Rod – Stainless Steel

When the requirements for pleasing aesthetics or corrosion protection are particularly high, stainless steel tension rods are the perfect solution. In stainless steel, typical material grades are 460 & 520 N/mm2 & the thread diameter range from M16 to M98

Another key feature to highlight in both CS & SS tension rods is that companies like Dextra offer tension rods with rolled threads which are very good in fatigue performance. They also provide fatigue test certification for their products.

Compression Struts – Carbon Steel

Compression struts are carbon steel tubes with circular hollow section with typical thread dia range from M16 to M103. In this product also Length adjustment of the assembly is possible at each fork end.

- **Surface Finish**
    - **Carbon Steel**

		
Plain surface (Black Steel)	Primer Finish	Galvanized Finish

Stainless Steel

	
Satin Finish Ra 0.4 (N5) as per ISO 1302	Mirror Finish Ra 0.1 (N3) as per ISO 1302

- Summary benefits

    - **Fast installation with forks & pin connections.**
    - **Couplers to achieve longer tendon length.**
    - **Turnbuckle to allow length adjustment.**
    - **Sagging correction by rotating turnbuckles or by turning the bar itself.**
    - **Pre-stressing at turnbuckle**
    - **Rolled threads for better fatigue performance**
    - **Smaller bar diameters for better aesthetics.**
    - ***Less tonnage = lower cost.***
    - **Environment friendly & sustainable product reducing carbon footprint**

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