BS-96

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GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

GUIDELINES ON UNDERWATER INSPECTION OF BRIDGES

REPORT NO. BS-96

JULY, 2008

ISSUED BY

RESEARCH DESIGNS AND STANDARDS ORGANISATION
LUCKNOW - 226011

PREFACE

A four member committee for “Guidelines for Underwater Inspection of Bridges” was set up by Railway Board vide letter No. 2003/CE-1/BR-III/2(Pt) dated 23.1.2007. The members of the committee as nominated by Board include:

(i) EDB&S/RDSO- Convener
(ii) CBE/ Central Railway, Mumbai
(iii) CBE/Southern Railway, Chennai
(iv) Sr. Professor/Bridges, IRICEN, Pune

Shri A.K.Sinha who was earlier working as CBE, S.Railway is now posted as CE/Works, S.Rly and is closely associated with this Pilot project. Keeping in view of his past experience on Under Water Inspection and association in preparation of guidelines, he was requested to continue in the committee in place of CBE/S.Rly. This has also been advised to Railway Board vide RDSO’s letter No.CBS/UWI dated 7/10.12.2007.

The commeette was required to critically examine and analyze the details and outcome of Pilot Project on “Under Water Inspection of Bridges” completed by Central Railway. The committee was also directed to critically analyze the studies done by RDSO and IRICEN and provisions in International codes/manuals.

The committee had deliberated and critically analyzed the details and guidelines for Underwater Inspection of Bridges based on international practices prepared as outcome of the Pilot Project on Underwater Inspection of Bridges undertaken by Central Railway. RDSO has also prepared a report on underwater inspection and issued the same as BS-40, “Guidelines for Underwater Inspection of Bridges” in Oct, 2001. IRICEN has also brought out a publication on Underwater Inspection of Bridges. The committee has gone through these documents carefully and had detailed deliberations and has prepared report on ‘Guidelines on Under Water Inspection of Bridges”.

Based on above studies, observations as communicated by Railway Board vide letter No.2003/CE-I/BR-III/2 (Pt.II) dated 14.7.2008 and also provisions in Indian Railway Bridge Manual, Guidelines on Underwater Inspection of Bridges is being published in supersession of earlier guidelines BS-40 issued by RDSO. These are general guidelines and the process of inspection may need to be modified depending upon the condition of site. The views expressed in this guideline are subject to modification from time to time in the light of more information. Further, they do not necessarily represent the views of the Ministry of Railways (Railway Board), Government of India. The booklet is the property of RDSO and is meant essentially for official use. It may not be loaned, reproduced in part or in full nor quoted as an authority without the permission of the Director General, RDSO.

Place: Lucknow (Piyush Agarwal)
Dated: 29-07-2008 EDB&S/RDSO

C O N T E N T S

GUIDELINES ON UNDERWATER INSPECTION OF BRIDGES

1. GENERAL

1.1 Introduction

Bridges that cross waterways often have foundation and substructure elements located under water to provide the most economical overall design. It is important that entire bridge is inspected at specified interval not only to ensure safety of the bridge, but also to initiate any repair/rehabilitation work well in advance so that the bridge remains functional. Unfortunately, the condition of substructure and foundation under water cannot be easily determined as the condition of those parts of the bridge located above water. The environment under water is harsher and requires special equipments and methods. As these elements are continuously submerged, underwater inspection and management techniques must be undertaken to establish their condition so that unsafe condition can be avoided.

In general, the term "underwater inspection" is taken to mean a hands-on inspection requiring underwater breathing apparatus and related diving equipments. However, it is a more specialised operation than a routine bridge inspection. Specialised equipments and skilled divers are required to carry out a satisfactory under water inspection. The bridge inspector and the diver must be able to act as a team in relaying the proper information to each other and coordinating the whole inspection procedure. As the underwater inspection is highly skilled and expensive, the selection of bridges for inclusion in under water inspection programme should be done in a careful manner. A majority of major railway bridges are built over waterways, and bridge failures can occur due to underwater problems. Thus, underwater bridge inspections are essential to maintain the safety of the bridges. If underwater inspections are not performed regularly serious damage can occur and develop without being detected before it is too late.

The present guidelines are in supersession of RDSO's earlier guidelines issued as BS:40 on "Guidelines for Underwater Inspection of Bridges". These are general guidelines for inspecting officials to perform underwater inspection and required to be modified/supplemented specific to bridges with the approval of Chief Bridge Engineer of the Zonal Railway depending upon on site condition.

THE UNDERWATER INSPECTION (UWI) IS TO BE PERFORMED FOR THAT PORTION OF THE BRIDGE WHICH ARE SUBMERGED PERENNIALY UNDER WATER.

1.2 Bridge Selection Criteria

The existing provision on underwater inspection as per para 1107 (d) of Indian Railway Bridge Manual is as below:

"The substructure of the bridges which are normally under water should be inspected by adopting suitable methods which may include engaging of divers and special equipment".

Thus bridges requiring underwater inspection must be noted for individual inspection and inventory records must be compiled in a master list. For these bridges, the following information should be collected as a minimum pre-requisite and considered while planning its inspection. These are general in nature and do not deal with the planning of special types of underwater inspection.

- Type and location of the bridge
- Type and frequency of the required inspection
- Location of members to be inspected
- Inspection procedures to be used
- Special equipments requirement
- Dates of previous inspections
- Findings of the last inspection
- Follow up action taken on findings of the last inspection
- Type of foundation
- Elevation of bottom of foundation or pile/well tip.

1.3 Type & Frequency of Inspection

It is a good practice to schedule underwater inspection immediately after monsoon. It is best to schedule underwater inspection during that period of the year when the conditions are most favourable, such as during low water or low pollution Level or good underwater visibility. The dive should be timed for the period when the tide is stable for the bridges located in the backwaters.

Underwater inspections are of three types:

a) **Routine inspection**- This is an underwater visual/feel inspection. This inspection is often characterized as a “swim by” inspection. The basic purpose is to detect obvious damages or problems. This inspection should be of Level I. This inspection shall be carried out once in a year. This is the maximum interval at which all underwater elements of a bridge, even if it is in sound condition, must be inspected. Any problems identified during the inspection may necessitate going in for Detail Inspection.

b) **Detail inspection**: This inspection is more detailed and directed towards obtaining limited measurements of damaged or deteriorated areas that may be hidden by marine growth. The marine growth needs to be cleaned for surface inspection and such cleaning is restricted to sample areas of the entire underwater structures. In addition to this, Detail Inspection shall also be done on those structures where problems have been identified/encountered during Routine Inspection. This inspection should be of Level II and shall be carried out once in five year. This is the maximum interval at which all underwater elements of a bridge, even if it is in sound condition, must be inspected. During this inspection, when there is an apparent damage to the bridge or any problem is visualised/identified which may necessitate further investigation, Level III inspection should be carried out. However, sectional Sr.DEN/DEN should first ascertain the necessity of carrying out Level III inspection before instructing to carry out this inspection.

c) **Special inspection**: This inspection is an unscheduled Inspection. This inspection is required to be carried out in the following cases:-

- After unusual floods.
- After vessel impact (unless it is obvious that no damage has occurred).
- Build-up of debris at piers and abutments (horizontal forces on the structures and scour because of reduced cross section of the river).
- Unusual prop wash from vessels.
- In case of settlements or other evidence of excessive scour.

This inspection should initially be of Level I. However, higher level of inspection can be planned if required.

1.4 Level of Inspections

There are three Levels of underwater bridge inspections:

- Level I: **Visual inspection,** a feel inspection using large sweeping motions of the hands where visibility is limited. If needed, a clear box can be used. This inspection is supplemented by water depth soundings. This inspection is often characterized as a "swim by" inspection.

- Level II: **Detail visual inspection** that includes cleaning of areas for closer inspection and obtaining limited measurements of damaged or deteriorated areas that may be hidden by marine growth.

- Level III: **Investigation** of specific components using Non Destructive Testing (NDT). The purpose of special instruction is to assess the material state/strength.

1.4.1 Level I inspection

This inspection is performed to determine the physical and functional condition of the structure, identifying changes from previously recorded conditions. Level I inspection is a visual inspection on entire underwater substructure of the structure to determine obvious major damages/problems.

The Level I inspection should be carried out by an experienced diver guided by an experienced team leader and following result from the inspections are expected:

- Water depth sounding and scour around piers and abutments.
- Verification of the continuity of the piers in full length.
- Registration of spalling.
- Registration of corrosion.
- Registration of cracks larger than 0.2mm.
- Registration of severe damage in general.

The report of a Level I inspection should comprise of the following:

- Method and extent of investigation.
- Background material.
- Recording of deficiencies/important aspects requiring notice of higher authority.
- Assign condition rating number of the underwater bridge components.

- Need for further inspections (Level II or III) – if required.
- Photos and video recordings (Not mandatory). Specific requirement, if any, for photo/video recording should be ascertained by Chief Bridge Engineer of the Railway.

1.4.2 Level II Inspection

The Level II inspection may be required to be conducted to detect any deficiency not readily apparent using Level I inspection. The Level II inspection should also be carried out on those underwater elements where problems/deteriorations were noted during Level I inspection. The marine growth, like algae/barnacles/ sea grass/ snails/ oysters etc. if any, must be cleaned for surface inspection. One or more of the following conditions may dictate the need for a Level II inspection.

- Inconclusive results from a Level I inspection
- Critical structures whose loss would have significant impact on life or property
- Unique structures whose structural performance is uncertain
- Prior evidence of distress
- Adverse environmental conditions such as brackish and polluted water.

The Level II inspection should be carried out by an experienced diver guided by an experienced team leader. The result of the Level II inspection is a recording of damage in the selected areas. The damage should be measured and the extent and severity of the damage should be documented. The cleaning of the substructure components is to be performed in three different water depths. The thoroughness of cleaning should be governed by what is necessary to identify the condition of the underlying material. A clear water box and water jet cleaning equipment may be used if necessary. During the inspection, damage or deterioration (spalling, corrosion, cracks, etc.) or corrosion should be detected and measured, and the extent and severity of the damage should be documented.

Following results are expected from inspection:

- Registration of spalling.
- Registration of corrosion.
- Registration of cracks.
- Registration of severe damage in general.

As guidance, bands for cleaning of piers and abutments should be approximately 30 cm wide. The bands shall normally be located in the splash zone (low waterline), the mud line (bottom of river) and at construction joints or other structural details. If no joints exist the area could be placed midway between the low waterline and mud line. When selecting the areas for cleaning one should not only concentrate on damaged and suspicious areas, but should also include apparently undamaged areas.

The report of a Level II inspection should comprise of the following:

- Method and extent of investigation.
- Background material.

- Recording of Deficiencies/important aspects requiring notice of higher authority.
- Assign condition rating number of the underwater bridge components.
- Need for further inspections (Level III) – if required.
- Photos and video recordings

1.4.3 Level III Inspection

A Level III inspection is carried out to determine in detail the type, extent and cause of damage. Furthermore, the Level III inspection should evaluate the future development of damage. In this way, the Level III inspection forms the necessary basis for the detailed assessment of the damage and the preparation of the rehabilitation design. A Level III inspection is a highly detailed inspection of critical components or components where extensive repair or possible replacement is contemplated. During the Level III inspection hidden or interior damage must be detected, loss of cross sectional area must be detected and the material homogeneity must be evaluated. The Level III inspection includes extensive cleaning, detailed measurements and selected Non Destructive Tests (NDT).

The tests are planned using all available information from the drawings, previous underwater inspections of the bridge, underwater inspections of similar bridges and the knowledge and experience of the persons performing the underwater inspection. On this basis a “hypothesis” concerning the cause of damage, the total damaged area and the condition of the damaged area may be formulated.

On the basis of the visual underwater inspection (Level I and II inspections) and prior knowledge the substructure may be divided into homogeneous areas. A homogenous area is defined as an area where the present Level of deterioration and parameters affecting the deterioration of the substructure exhibits only a random variation. Consider for example a bridge pier in saline water. The chloride surface concentration will be large in the tidal and splash zones. The chloride surface concentration will decrease with increasing distance from the mean water Level. In this case it makes no sense to compare results from different piers if the tests are not performed at the same distance from the mean water Level. To overcome this problem the piers may be divided into homogenous areas.

If the test results do not confirm the hypothesis regarding the cause of damage, the hypothesis must be revised. It may be necessary to perform supplementary tests to confirm the revised hypothesis.

The scope of Level III inspection can vary substantially by the type and severity of event. Inspection must be sufficient to determine the need for emergency load restriction or closure of bridge to traffic and to assess the Level of effort necessary to repair the damage. If measurable damage has occurred, inspections must evaluate section loss, misalignment of members, and loss of foundation support if any. Situations that may warrant Level III inspection include:

- Floods – bridges located in streams, rivers and other waterways with known or suspected scour potential.

- Build-up of debris at piers or abutments – this material build up effectively widens the unit and may cause scouring currents or increase the depth of scour.
- Evidence of deterioration or movement – many underwater deficiencies only become apparent above water when the distress extends above the water line or is manifested by lateral movement or settlement.
- Significant earthquake – bridges also need to be inspected after an earthquake where structural damage is expected.

NDT methods which can be used for under water inspection are

1. Ultrasonic Thickness Gauge - Steel
2. Ultrasonic Testing - Concrete and steel
3. Cover-meter – Concrete
4. Schmidt Hammer - Concrete and masonry
5. Chloride Content - Concrete
6. Coring Equipment - Concrete and masonry
7. Evaluation of Concrete Cores – Concrete
8. Crack Measuring Gauge - Concrete and masonry
9. Impulse Response Equipment – Concrete
10. Impact-Echo Equipment - Concrete and masonry
11. Half-Cell Potential – Concrete

For details of NDT method for concrete structures may be referred to in BS Report No : 48 – 2002 – “Guidelines for Inspection Maintenance and Rehabilitation of Concrete Bridge”.

2.0 TYPES OF DAMAGE

Different types of damages observed are as under -

2.1 General structural damage

- Permanent deformations (deflections/displacement)
- Tilt/settlement
- Abnormal vibration (too slender structures/insufficient supports)

2.2 Damage due to water

- Scour
- Ponding of water
- Deposition
- Debris and vegetation
- Difference in Level
- Erosion
- Material loss/disintegration
- Silting at culvert

2.3 Damage on concrete structures

- Cracks
- Spalling

- Corrosion of reinforcement
- Wear and abrasion
- Material deterioration
- Impact damage
- Fracture
- Weathering
- Honeycombing

2.4 Damage on steel structures

- Corrosion
- Cracks
- Loose connections (loose bolts)
- Unintended eccentricities
- Impact damage
- Fracture

2.5 Damage at masonry structures

- Deteriorated stones/bricks
- Deteriorated joints
- De-bonding of stones/bricks to form cavities
- Cracks
- Unintended eccentricities
- Overloading
- Moisture penetration
- Impact damage
- Fracture

3. UNDERWATER INSPECTION METHODS

Method for underwater inspection of a bridge depends on the age, type and extent of damage detected in previous inspection, inspection intensity Level, prevailing site/local conditions, etc. Selection of a particular method of inspection as well as the inspection intensity Level will determine the effectiveness of inspection as well as the inspection cost.

The underwater Inspection of the bridges involve divers going under water for the purpose of inspection and record videography as per the instructions of the Engineer-in-charge. In case any wading inspection is conducted, such an inspection will not be termed as “under water inspection”. The two methods of carrying out under-water inspection, in – vogue at present, are outlined below --

a) Scuba diving
b) Surface supplied air diving

3.1 Scuba diving

The acronym “Scuba” stands for Self Contained Underwater Breathing Apparatus. In Scuba diving, the diver is provided with compressed air supply through a Scuba tank, which is strapped to the diver’s back (Fig. 1). Air is inhaled from the Scuba tank and the exhaust is vented directly to the surrounding water.

Fig.1 Oxygen tank strapped to Scuba diver's back

The minimum equipments required are scuba, wet/dry suit (thermal protection), life preserver, weight belt (to counter buoyancy), knife (for emergency), face mask (for breathing), swim fins (for navigation), depth gauge (to estimate depth), wrist watch, etc. The wet suit is suitable for temperatures more than 10^0C and dry suit for temperature less than 10^0C. Depending on the site conditions, additional equipments may be resorted to.

This method is specially suited for making inspection when mobility is prime consideration or many dives of short durations are required. Scuba equipment weighs above 30 kg and requires no elaborate support operation. It has the advantage that the diver does not have to drag an air hose behind him. Generally, the maximum sustained time and working depth in scuba diving are 20 minutes at 20 m depth, 15 minutes at 30m depth and 10 minute at 40 m depth. Scuba diving with mixed air is used for the same situations as normal Scuba diving, it has the advantage of extending the diving time to a great deal. The disadvantage is that it needs more preparation.

There is no communication arrangement in standard Scuba equipment. However, Scuba diving can be provided with additional communication arrangements. This can be wired or wireless communication. This has many advantages. During the inspections, the diver can report directly to the surface and the surface engineer can guide or give instructions to the diver.

Advantages

- Most suitable for short duration dives
- Not always necessary to have boat,
- Lower operating cost,
- Low effort dive,
- Allows increased diver mobility,
- Best in low velocity currents.

Disadvantages

- Limited air supply,

- Lack of voice communication with surface (can be overcome with additional communication equipments).

3.2 Surface supplied air diving

Surface supplied air diving (Fig. 2) requires minimum equipments such as wet/dry suit (thermal protection), life preserver, weight belt (to control buoyancy), knife (for emergency), face mask (for breathing), gum boots/swim fins (for navigation), depth gauge (to estimate depth). Air is supplied to the diver through umbilical hoses connected to the surface air compressor tank. It requires more equipment than the Scuba diving. In addition to the air hose, a communication cable, a lifeline, and a pneumatic fathometer are usually attached to the diver.

Fig. 2 Surface supplied air diving

Surface supplied air diving is well suited for high stream flow velocity up to a maximum of 4 m/s, polluted water, and long duration requirements. Oxygen can be mixed with air (Nitrox) to extend dive time in shallow water and Trimix or Heliox will make it possible to dive deeper than 36 meters.

Advantages

- Long duration dives/deep water diving (more than 36 m),
- Unlimited air supply,
- Backup system available,
- Better for low water temperature and high-effort dives,
- Safe line attachment to surface,
- Better for high velocity currents,
- Better in polluted and turbid water,
- Allows direct communication for audio and video,
- Topside depth monitoring is simplified.

Disadvantages

- Large size of operation,

3.3 Method Selection Criteria

A number of factors influence the proper underwater inspection method. Depth of water alone should not be the sole criteria in determining whether a bridge can be inspected by skin diving (without suit) or it requires the use of diving equipment. Some of the factors are:

- Water depth
- Current velocity
- Underwater visibility
- Substructure configuration
- Streambed condition
- Debris

4. UNDERWATER PHOTOGRAPHY AND VIDEO EQUIPMENTS

Still photographs and video records facilitate in-depth documentation of underwater inspection. Video systems can provide pictorial representation of existing conditions, transmit visual data to topside personnel for analysis and interpretation, and provide a permanent record of the inspection process. The photography system used in underwater inspection includes still-photography equipment, video recording system, video imaging system and any accessories.

4.1 Still photography equipments

Still photography shall be done using digital camera of minimum 5.0 Mega pixels with 10x optical zoom. Wide-angle lenses are preferably used where visibility is limited and camera is required to be placed close to the object.

Suspended particles often dilute the light reaching the object and can reflect light back into the lens. When visibility is low, clear water boxes can be used. The boxes are made of clear plastic and can be filled with clean water. By placing the box against the object area, the dirty water is displaced and the camera shot can be taken through the clear water.

4.2 Video equipments

Video equipments are available either as self contained, submergible units (Fig. 3) or as submersible cameras having cable connections to the surface monitor and controls. The latter type allows a surface operator to direct shooting while the diver concentrates on aligning the camera only. The operator can view the monitor, control the lighting and focussing and communicate with the diver to obtain optimum image. The camera should be capable of taking image at zero Lux with LEDs on.

Fig. 3 Self-contained submergible video camera

4.3 Under Water Lighting

There are three main problems in turbid water, which limit the viewing performance of an underwater camera. These are:

- Absorption
- Refraction
- Reflection

Absorption reduces the amount of illuminating light that reaches the object from the light source. It also reduces the amount of light reaching the camera from the object. This combined absorption of light limits the maximum distance between the camera and the object. The viewing range is proportional to the power of the light source, and the light sensitivity of the camera used. The process of absorption of light can be overcome by using higher-powered lighting, or by using more light sensitive cameras or both combined.

The process of refraction causes dispersion of light from the light source across a larger area than would occur in clear water, thus reducing the intensity of the light beam. The light coming back from the subject to camera is also reduced and scattered in a similar fashion causing loss of contrast and image detail in the video signal. There is little that can be done to overcome the effects of refraction. Image definition and contrast in turbid water condition will never be as good as in clear water condition. The use of image enhancement techniques to artificially sharpen up the image can be of some benefit, but these do not significantly improve the amount of information that the image provides.

Reflection is probably the most critical factor for the performance of cameras in turbid water. The suspended particles in the path of illuminating light reflect a portion of the illuminating light directly back into the camera. This backscatter, can often be limiting factor in the use of underwater visual imaging system in turbid water. The illuminating light reflected back from the suspended particles tends to “swamp” the imaging light from the subject. The problem of reflection can be minimised by carefully placing the flash away from the axis of the camera and at angle to provide reasonable coverage of the subject as shown in Fig 4.

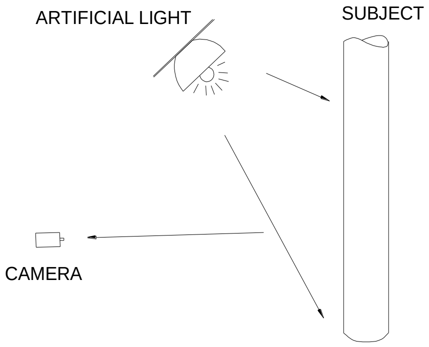


Fig .4 Lighting arrangement to avoid reflection

4.3.1 Use of scattered lighting

In this arrangement, a very high powered, tight beam spot light (beam angle less than 10^0) is used. The lamp is directed near but not at the object. The object is illuminated by scattered light from the high power lamp beam along the light path (Fig. 5). Because the illuminating light is scattered and diffused, the effect of backscatter tends to be much reduced as there is little directly reflected light.

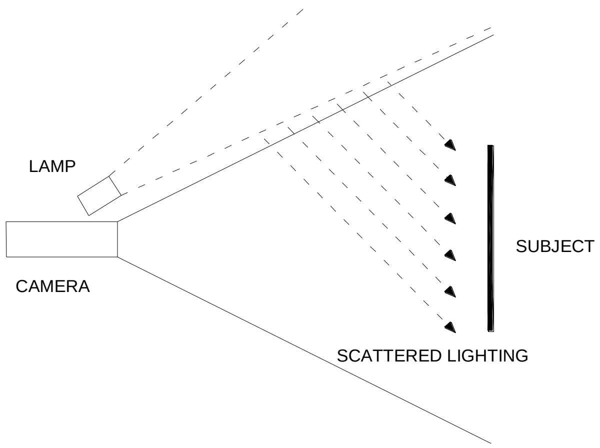


Fig. 5 Arrangement for scattered lighting

Advantages

- Less severe backscatter than direct illumination
- Not very critical to alignment

Disadvantages

- Needs very high power
- Uneven object illumination
- Relies on turbidity to work. Not suitable in clear water
- Not suitable for close-up inspection as there will not be enough scatter.

4.4 Underwater Torches

There are various kinds of underwater torches. The underwater torch should be of minimum capacity of 3 Watt for skin diving and minimum 10 Watt for Scuba/Surface area supplied diving. The output of the torch for skin diving should be 80 Lumen (Lm) with a burn time of 3 hours and for other types a minimum of 450 Lumen (Lm) with a burn time of 270 minutes.

4.5 Strobe Torch Light

In case, the underwater inspection to be carried out under turbid conditions and at deep water depth particularly in a relatively dark area, then the diver must carry the strobe torch light. The strobe torch light should be of minimum 3 Watt capacity. All the underwater torches should be of LED type.

5. OTHER CONSIDERATIONS FOR UNDERWATER INSPECTION

Once a diver enters the water, their environment changes completely. Visibility decreases and is often reduced to near zero due to muddy water and depth. The diver not only has reduced perceptual capabilities but is less mobile as well. Manoeuvrability is essential for underwater bridge inspections. In many cases, artificial lighting is required. In addition to above, certain special situations are encountered, which require special consideration.

5.1 Dealing with current

Most waterways have low flow periods when current will not hinder an inspection. Diving inspections should be planned with this consideration in mind. Divers can work in current below 1.5 knots with relatively little hindrance.

As current increases, special precautions are required. The simplest is to use bottom anchors to tether the diver. In swifter current, shielding devices and special anchor systems may be required.

5.2 Dealing with drift and debris

The drift and debris are sometimes carried with water during high floods. This mostly consists of logs and limbs of trees. Often these debris are located on the lower parts of the substructure and cannot be detected from the surface. The build-up can be so thick as to prevent access to major portions of the underwater substructure. The removal of the drift and debris must be provided for if an inspection of the underwater structure is to proceed. While in many cases it can be removed by the inspection divers, heavy equipment such as a hoist or underwater cutting devices, are sometimes required. Divers must also have a safety concern about the build-up of debris near a bridge. Occasionally, debris can be quite extensive and can lead to entanglements or sudden shifts which might entrap the diver.

5.3 Decompression sickness

Since the majority of bridge inspections are in relatively shallow water and of short duration, decompression problems rarely occur. However, multiple dives have a cumulative effect and the no-decompression time limit decreases rapidly at greater depths. There is no limit placed on the duration of diver up to 18m depths. Whenever depth of diving exceeds 18m, decompression should be carried out as per Cl. 6.2 of IS 10291-1982. Divers should routinely track their time and depth as a safety precaution.

5.4 Diver's qualification

The requisite qualification for divers and diving supervisors are given in IS:10291 –1982, which stipulates that the diver should be at least 18 years of age and should not have any sickness at the time of Diving, as any sickness would get amplified during the Dive. He should be certified by the qualified medical practitioner within previous 6 months. Diver should have thorough knowledge of diving signals.

Certification of the diver by Navy/Indian Register of Shipping (IRS) is mandatory for all types of divers. In addition to this, scuba divers should be trained by scuba diving PADI (Professional Association of Diving Instructors).

5.5 Divers in a team

Diving team should have at least 3 divers – that is, apart from the diver, one partner and one stand by on the surface are required as goes the saying in diving arena "Never dive alone, always dive with a partner".

5.6 Safety precautions

5.6.1 The working agency should have its own diving safety manual, which should be strictly followed. This manual should include:

- Safety procedures and checklist for diving operations
- Assignment and responsibilities of dive team members
- Equipment procedures and checklist
- Emergency procedures in case of equipment failures, adverse environmental conditions, diver illness or injury

5.6.2 First Aid (Standard First Aid Kit) Box should be available. For major works requiring engaging Six Divers/Two Diver-Teams or more; preferably a qualified doctor should be present on the Boat. Before execution of underwater inspection, it is desirable to take the divers to the nearby medical centre and get them medically examined as a precautionary measure so that in case of any mishap, the medical centre has the necessary details of the divers. All divers, including equipments, should be covered by Insurance.

Before taking up diving operation, the supervisor must ensure that:

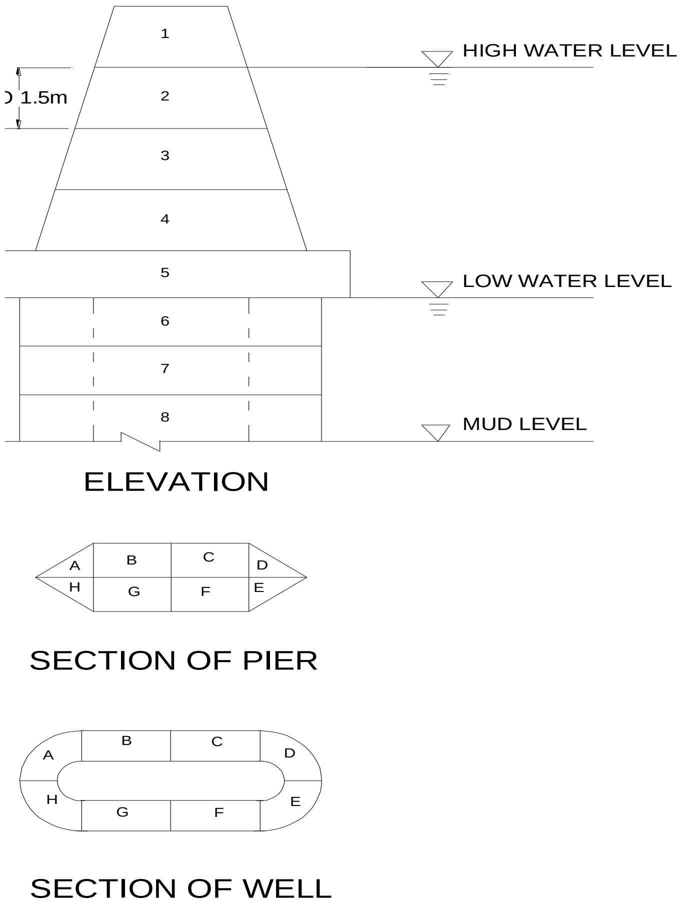
- All the equipments are in working condition

- Each diving operation is thoroughly planned
- Arrangements are in place to take care of emergencies
- Sufficient number of signalmen and standby divers are present at site

6. DOCUMENTATION AND REPORTING

6.1 Documentation

The underwater inspection of a pier/abutment should include all pier/abutment surfaces between the high waterline and the mud line. The entire pier surface may be divided into suitable number of segments along the perimeter, each covering a spacing of 1 to 1.5 m. A typical arrangement is shown in Fig. 6. This facilitates identification of location of defects.



6.2 Reporting

Level I and Level II inspection should be performed in the presence of sectional AEN while Level III inspection should be performed in the presence of sectional Sr.DEN/DEN. For each inspection, a report is to be prepared and is required to be maintained separately bridgewise by sectional AEN. The outcome of this report are specifically to be recorded in the bridge register. The Level I & Level II inspection reports should be sent to sectional Sr.DEN/DEN for scrutiny and for planning of works. Level II & Level III inspection reports along with the detailed remarks should be sent to Chief Bridge Engineer for scrutiny and further instructions.

The report includes an evaluation of the assessed conditions and recommendations for further action. The report should provide sufficient technical detail to support the assessment and recommendations. The report for Level I, II & III shall include the following:

- Identification and description of all major damages and deterioration in the structure element-wise.
- Estimate of the extent of minor damage and deterioration.
- Assessment of the general physical condition.
- Cause of damage/deterioration if known.
- Water depths at each structural element.
- Recommendations for types of maintenance and repairs required.
- Recommendations for types and frequencies of future underwater inspections.
- Water visibility, tidal range, water current and any other pertinent environmental conditions.

Since underwater inspections are specialised, a report format such as one presented in the following Table is recommended. The objective of the guideline is to facilitate the writing of comprehensive, standardised, and usable reports.

Format for inspection reports

Report Cover → **Title Page** → Executive summary → Table of contents → List of figures → List of photographs/videotapes → List of tables	
Section 1	Introduction
1.1	Background / Objective
1.2	Location and details of structure
Section 2	Inspected structural element
2.1	Name of structural element
2.2	Description of the element
2.3	Observed inspection condition
2.4	Structural condition assessment
2.5	Recommendations
	Repeat the above as necessary for each element
Appendices	
A	Inspecting Agency and key personnel
B	Inspection procedure / Level
C	Pertinent background information
D	References

7. UNDERWATER INSPECTIONS AGENCIES

Details of some of the underwater inspection agencies is given in annexure I. This is based on the response of firms against an advertisement floated by RDSO, Lucknow wherein firms dealing with underwater inspections were requested to send their details. Few more firms whose details were available from the market have also been added. The list is only indicative and not exhaustive and can be many more firms. It is suggested that antecedents of these firms must be verified before awarding them any work.

8. CONCLUSION

With the ageing profile of the bridges there is a strong need to develop and implement a regular program for underwater inspection of bridges. All the Brtidge Engineers have to participate and contribute their best for successful implementation of underwater inspection.

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9. BS-40: RDSO Guidelines for Underwater Inspection of Bridges, Oct,2001.

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Annexure I

List of underwater inspection agencies

S.N.	Name	Address	Email
1.	M/s Infrastructure Engineers inc.	1211, 12th Street, St.Cloud FL 34769, USA Ph –407-957-1650	dresser@infrastrucureengineers.com
2.	M/s Marine Engineering System Co. Inc	5030 Old Kings Road NW, Jacksonville, FL32254 USA, Ph	MescoDive@aol.com
3.	M/s Mainstream Commercial Divers Inc.	322 C, C.Lowry Drive, P.O.Box No.1426, Murray K.Y.42071, USA, Ph 270-753-9654	info@mainstreamdivers.com
4.	M/s W J Castle & Associates	P.O.Box 586, Lumberton NJ 08048, USA Ph-609-261-2268 Fax-609-261-3422	bcastle@wjcastlegroup.com
5.	M/s Wilbur Smith Associates	Santosh V.Krishnan; India Country Manager; # B-009, Sobha Sapphire S.N.15 Sahakar Nagar P.O. Bangalore 560 092, India Ph & Fax-080-23636293	santoshvk@wilbursmith.com
6.	M/s L &T Ramboll	339/340, Anna Salai, Nandanam Chennai – 600035 Phone – 044-24331181	ltramboll@vsnl.com
7.	M/s Enviro Infra Tech	A – 320, Ganinath Nikunj Plot No.1 Sector 5 Dwarks, New Delhi – 110045 Phone-011-5087214	-
8.	M/s Jwalpa Enterprise Pvt. Ltd.	140, Vanasthali, Mandir Lane, Ballupur, Dehradun-248001, Uttaranchal Ph-0135-752942	-
9.	M/s Advanced Construction Technologies Pvt. Ltd. In association with Disco Tech. Dubai	19, Cenotaph Road, Teynampet, Chennai – 600 018 Fax.044-24342272	dubai@dicotech.com
10.	M/s Sea Swift Enterprises	B-11, Fashqua Shopping Centre, Station Road, Santa Cruz (W) Mumbai – 400 054 Ph-022-6041333/43 Fax-022-6056697	Seaswift@vsnl.com
11.	M/s United Divers Pvt. Ltd.	201, 'SAIDEEP' 2nd floor, NG Acharya Marg, Chembur, Mumbai – 400 071 Fax-022-5565636	United_ divers@ vsnl.com

12.	M/s S.J.Group Consulting Civil Engineers	196 Jawahar Nagar, Goregaon(W) Mumbai 400 062, Ph-022-8732517 Fax-022-8759710	sjgroup@vsnl.com
13.	M/s Sverdrup Civil Inc.	242, Okhla Industrial Estate Phase III, New Delhi – 110 020 Ph-011-6319901, Fax –011-6319907	-
14.	M/s Construma Constultancy Pvt. Ltd.	2nd Floor, Pinky Plaza, 5th Road, Khar, Mumbai-400 052, Ph-022-26487415, Fax-022-26463181	ccpltd@bom3.vsnl.net.in
15.	M/s Aqua Space Diving Services	39/4024/B Sreekandath Road, Ernakulam Cochin-682016, Kerala, Ph-369981, Fax-0484-323424	-
16.	M/s Intertech Sales Corporation	Shagun, S-27 Rajouri Garden, New Delhi –110 027 Ph-011-5104288, Fax-011-546320	interec@bol.net.in
17.	M/s Sea Lion Diving Services	E 1/5, Municipal Complex, Stadium Road, Visakhapatnam-530001 Ph – 0891-2726148	-
18.	M/s Dynasoure Concrete Treatment Pvt. Ltd.	419, New Sonal Service Industrial Estate, Link Road, Malad West, Mumbai - 400064 Ph – 022-28821668	-
19.	M/s B.V. Construction	Shop No. 25, APHB,Vidya Nagar, -Hyderabad-44.	
20.	M/s Hyderabad Telivisions, Panjagutta, Hyderabad	Plot No.9, Janata Flats, Kanti Shikara Complex. Panjagutta, Hyderabad-82.	