Appendix 7: Inspection Methods

1.0 INSPECTION METHODS

Various types of Non-Destructive Evaluation (NDE) methods used for the inspection of composites to detect defects are summarized below. NDE methods developed to date can be classified into the following four categories according to the specificity of information provided by the given method:

- Level I Methods – Methods which only identify if damage has occurred;
- Level II Methods – Methods which identify if damage has occurred and simultaneously determine the location of damage;
- Level III Methods – Methods which identify if damage has occurred, the location of the damage, and estimates the severity of the damage;
- Level IV Methods – Methods that identify if damage has occurred, the location of the damage, estimate of the severity of the damage, and evaluate the impact of damage on the structure.

The various inspection methods and the tentative classification of the methods in the various categories are briefly discussed below:

1. *Visual Testing:* Visual testing (VT) is the most common and fundamental NDE test performed. Visual testing requires some level of experience on the part of the inspector to detect defects. Visual inspection is used to check for signs of wear, degradation or delamination of the top surface/skin (or the bottom surface/skin) from the core. Also the inspector should look for blisters (usually caused by too-rapid cure or moisture in the resin), impact cracks, freeze/thaw cycling damage, crazing (pattern of fine cracks on or beneath the surface), holes in the panel, crushed panels, voids, and dry spots. This method can be classified as a Level I method or a Level II method depending on the type of observation.

2. *Tap Testing:* Tap testing is the second most common type of NDE test performed on an FRP Bridge deck. Tap testing is an NDE practice that is fast, low cost and effective for inspecting composites. Inspections are based on the sound of a coin tap and are subjective and do not provide quantitative information. Electronic units are available which provide a relative indicator of a defect based upon a transducer. Although the electronic units provide a more consistent and documentable relative sense of a defect than the coin tap test, the coin tap test is much faster and maybe more suitable for initial inspection. The tap test method can be classified as a Level II method.

3. *Ultrasonic Testing:* Ultrasonic testing utilizes high-frequency sound in the range of 20 K-hertz to 25 M-hertz to evaluate internal volumetric condition of the material. A transducer (probe) with a piezoelectric crystal transmits high-

frequency sound into the specimen and receives the returning signals for interpretation by displaying the signal in the form of an "A" scan or a "C" scan. The "A" scan display is similar to an oscilloscope display giving the time of flight and reflection amplitude data. The "C" scan display requires the use of an automatic rectilinear system and displays a plan view of the detected defects. Various couplants are used between the specimen and the probe. Typical discontinuities which are detectable include: delaminations, disbonds, resin variations, broken fibers, impact damage, moisture, cracks, voids, and subsurface defects. This method can be classified as a Level II method.

4. *Laser-Based Ultrasound:* Laser-Based Ultrasound testing is a remote nondestructive inspection technique that combines the capabilities of ultrasonics for the detection, location, and sizing of flaws in a material, with the capabilities of optics. The technique is based on the use of a pulsed laser for the generation of ultrasonic waves that propagate inside the material and on the detection of these waves with a second laser coupled to an optical interferometer. This method can be classified as a Level II method.

5. *Acoustic Emission:* Acoustic Emission testing is an NDE method whereby an elastic wave, in the range of ultrasound usually between 20 KHz and 1 MHz, is generated by the rapid release of energy from the source within a material. The elastic wave propagates through the solid to the surface, where it can be recorded by one or more sensors/transducers. Acoustic emission (AE) listens for emissions from active defects and is very sensitive to defect activity when a structure is loaded. One of the advantages compared to other NDE techniques is the ability to observe damage processes during the entire load history without any disturbance to the specimen. Typical discontinuities that are detectable include: some delaminations, some disbonds, and broken fibers. This method can be classified as a Level II or Level III method.

6. *Radiography:* A process of non-destructive testing which uses penetrating radiation such as X-rays or gamma rays. Differential absorption of the penetrating radiation by the specimen will cause absorption differences that can be recorded on radiographic film. Unlike ultrasonics, radiography cannot capture the volumetric characteristics of the defects, but rather higher resolution planar aspects of defects. Typical discontinuities which are detectable include: some delaminations and some disbonds depending on the orientation, voids, resin variations, broken fibers, impact damage, and cracks. This method can be classified as a Level II method.

7. *Thermography:* A heat source is used to heat a sample surface with a light pulse, and then an infrared camera is used to measure the surface temperature response to the flash. Subsurface variation in the sample cause slight changes in the wave IR energy that radiates from the surface of the part. Discontinuities in the material or differences in thermal conductivity cause gradients in the isothermal contours which are detectable. The advantage of active thermography for this application is that it is completely non-contacting, using remote heating and remote detection to

make the measurements. Typical discontinuities which are detectable include: delaminations, disbonds, impact damage, moisture, and voids. This method can be classified as a Level II or Level III method.

8. *Shearography:* Shearography is an interferometric system that uses an expanded beam of laser light that is reflected off the specimen. This is accomplished by fringe patterns caused by differential surface deformation and the coherence of laser light when projected onto a test object. There are two main steps in Shearography measurement. 1) Coherent Laser light illuminates the object in which the light reflected from the object is sheared. 2) A thermal, tensile, vibratory, or pressure load is applied to the test specimen to cause it to deform. When the object is deformed, the speckle pattern is slightly modified. Comparing the two speckle patterns (stressed and unstressed) produces a fringe pattern which depicts the relative displacement of two neighboring points. Typical discontinuities which are detectable include: delaminations, disbonds, impact damage, voids, and subsurface defects. This method can be classified as a Level II method.

9. *Modal Parameters Method:* In this method (Stubbs et al., 1997), the given structure is instrumented with an array of accelerometers and prescribed dynamic tests are performed to extract modal parameters (i.e. frequencies and mode shapes). Changes in the dynamic response of a structure are used to evaluate the structural condition. A detailed description of the field-testing and modal analysis is provided by Bolton et al. (1998) in a report to the California Department of Transportation. To perform the evaluation of the structure, modal parameters of the baseline structure (i.e. the as-built condition) as well as the existing structure are needed. In most cases baseline parameters of a structure do not exist; however, an approximation of the baseline modal parameters can be derived from the existing structure and a numerical model (finite element model) of the as-built condition. A stiffness sensitivity analysis is performed to evaluate the stiffness changes in the structure by determining the damage location index. The damage index identifies local potential damage of the structure at the member level. Then for each predicted damage location, the damage severity is estimated using a severity estimator. This method is classified as a Level III method. However, research currently being conducted by the California Department of Transportation and the University of California, San Diego is investigating a fracture mechanics based approach to the modal parameters method to raise it to a Level IV NDE method.

   This method however has several limitations, especially if it is to be used as Level III. The method is highly analytical and requires experimentation and scenario studies of analytical models and the instrumented structure. In order to capture damage at local levels, significant analytical effort has to be expended. Due to this, the costs and time associated with analysis and instrumentation could be very high. The need to conduct scenario studies further increases the time and cost of this approach, and the subjectivity involved in analytical modeling as well as the uncertainty in modeling difficult areas such as joints and connections makes this

method highly dependent on the qualifications and competence of the analyst. In addition, this method is unique to each bridge, and cannot be easily ported for use on all bridges.

Currently, the modal parameters method has been tried by some DOTs. For example, the California Department of Transportation tried this method on a handful of bridges for experimental health monitoring and NDE. However, in these cases, only primary members, i.e., beams or girders were evaluated. Two of the bridges were strengthened by FRP composites and one is a hybrid FRP composite bridge consisting of CFRP girders and a GFRP bridge deck (Kings Stormwater Bridge).

10. *Load Test Method:* This method is an NDE field performance evaluation test wherein the bridge is instrumented with strain gages, accelerometers, and displacement sensors. The instrumentation can serve the dual purpose of capturing the measurement response of the structure during load tests, and as an integral part in the long-term health monitoring system for the bridge. A new FRP bridge deck is typically tested with this method prior to opening up the bridge for service, and at routine intervals to assess potential changes in deck response with time. This method can be classified as a Level I method.

    This method was used on the Kings Stormwater Bridge by CALTRANS after a routine field inspection utilizing the Tap Test method identified possible separations between the CFRP filament-wound girders and the concrete. Load tests indicated that the overall response of the bridge had not degraded and that the performance was at relatively the same level as when the bridge was first opened to traffic.

2.0 COMPARATIVE EVALUATION OF INSPECTION METHODS, INCLUDING COSTS

This section presents a comparison of various NDE methods to a baseline test method. For comparison purposes, the designated baseline NDE test method is the visual inspection method. Also, for comparison of effort required to implement each inspection method, it was assumed that the baseline (reference) structure is a simple two-span, 4-lane bridge with clear access to both the top and bottom sides of the bridge. It was also assumed that the basic level of experience is established by completing the FHWA Bridge Inspection Training Course.

Highway agencies can assume that techniques other than visual and tap testing might be warranted and would be provided by consultants and inspection firms. Under these circumstances, inspection costs will be different than those of a highway agency inspection unit's routine visual inspection/tap testing-based protocol. For reference purposes, the following cost data for field testing and inspection services were gathered and are provided, based on the research team's experience. These can be used to estimate comparative costs for the reference structure to be inspected:

- Consultant Inspection Staff Hourly Fee (Technician/Inspector) - $50 to 100 hourly depending on experience, including test equipment

- Consultant Inspection Staff Hourly Fee (Engineer/Team Leader) - $90 to 150 hourly depending on experience, including test equipment

- It must be taken into account that radiography, X-ray, infrared and load test methods require specialized equipment and particular safety precautions. While the hourly rates above for inspection labor are representative for inspection staff skilled in these methods, additional daily fees ranging from a few hundred dollars to $1000 or more may accrue for procuring equipment or support for these more complex, capital equipment-reliant inspection methods.

Visual:

Visual testing requires an additional level of experience beyond the basic level on the part of the inspector to detect various types of subsurface defects in an FRP deck which may be masked by the deck overlay. An inspection manual showing the various defects in FRP decks and the visual signs of damage can assist a novice inspector to detect difficult defects such as signs of wear, degradation or delamination of the top surface/skin, blisters, impact cracks, freeze/thaw cycling damage, holes in the panel, crushed panels, and dry spots.

Instruments Required:

Tape Measure, Straight Edge, Markers, Hammer/Geologist pick, Flash light, Binoculars, Camera for documentation.

Time Required:

Reference Structure 2-4 hours.

Skill Level:

Medium Level of Experience
Advantages/Disadvantages:
Quick, Easy, Low Cost / Can not verify subsurface defects

Accuracy/Reliability:

Highly variable and inspector dependent. Also, subsurface defects cannot be verified.

Tap Test:

Little experience beyond the basic level is required for this method. The inspector taps the surface and listens to a distinctive change in frequency once a void or a delamination is encountered. Although the tap test method is quite basic, its application is dependent on type of FRP deck or detail inspected. For instance, tap testing is effective on sandwich/core type composite deck panels where delamination between the core and the top and bottom skins can easily be

detected, and not nearly as effective on pultruded deck sections such as the Duraspan deck.

Instruments Required:
Flash light, Tape Measure, Straight Edge, Markers, Large coin (also acceptable: screw driver, or light hammer), Chain for a chain drag to check wear surface delamination.

Time Required:
Reference Structure 4-8 hours.

Skill Level:
Low Level of Experience

Advantages/Disadvantages:
Quick, Easy, Low Cost / Not effective for all types of FRP decks, cannot determine the state of internal members.

Accuracy/Reliability:
Medium/Medium, depending on general location of defect; however, full characterization of defects cannot be established.

Ultrasonic:

Unlike visual inspection or tap testing, this inspection method demands a high level of skilled inspector to properly interpret the data. The inspector should be an American Society of Nondestructive Testing (ASNT) certified inspector. Whenever possible, it is recommended that a first pass visual inspection or a tap test be conducted, and if damage or defects are detected, then a localized follow-up evaluation can be performed using ultrasonic testing to further characterize the location, and size of the defect.

Instruments Required:
UT machine, Transducers (various types), Couplant

Time Required:
1-2 hrs per previously determined localized defect for each location

Skill Level:
High level of experience required, ASNT certification.

Advantages/Disadvantages:
Can obtain a permanent record of defect, can determine volumetric characteristics and location of defect / time-consuming, requires high level of experience.

Accuracy/Reliability:
Medium/Medium depending on access and defect location in member.

Inspection Frequency:
When required after 1st level inspection (visual/tap test)

Laser-Based/Non-Contact Ultrasonic:

Combines the capabilities of ultrasonics for the detection, location and sizing of flaws in a material, with the capabilities of optics. The advantage of this method is that it is a non-contact UT method in which couplant is not required.

Instruments Required:
UT machine, Transducers, Laser generator and receiver.

Time Required:
0.5-1 hr per previously determined localized defect for each defect location

Skill Level:
High level of experience required

Advantages/Disadvantages:
Can obtain a permanent record of defect, can determine volumetric characteristics and location of defect, faster than conventional UT / requires high level of experience, very expensive equipment.

Accuracy/Reliability:
High/High

Inspection Frequency:
When required after 1st level inspection (visual/tap test)

Acoustic Emission:

AE listens for emissions from active defects and is very sensitive to defect activity when a structure is loaded. One of the advantages compared to other NDE techniques is the ability to observe damage processes during the entire load history without any disturbance to the specimen. It is a global monitoring method that can direct conventional NDE methods to the localized problem areas that contain defects, and can be used to determine a flaw's growth rate. However, AE cannot accurately determine the configuration of the defect. This method also requires a high level of skill and sophisticated equipment compared to visual testing and tap testing.

Instruments Required:
AE sensors, couplant, Multi-channel AE system.

Time Required:
4-8 hour for setup, continuous sensing as load testing is applied.

Skill Level:
High level of experience required.

Advantages/Disadvantages:
Quick, easy, high sensitivity, early detection of flaws, can evaluate/monitor globally for defects, can greatly reduce the area to be scanned by other NDE methods. Full characterization of defects cannot be established, also defects that are neither growing nor moving do not produce AE and, thus, cannot be detected.

Accuracy/Reliability:
High/Medium since full characterization cannot be established.

Inspection Frequency:
At same frequency as routine inspection

Radiography:

Differential absorption of the penetrating radiation by the specimen will cause absorption differences, which can be recorded on radiographic film. Unlike ultrasonics, radiography cannot capture the volumetric characteristics of the defects, but rather higher resolution planer aspects of defects, and defect resolution is dependent on the orientation of the defect with respect to the source and the film. For example, if a plainer delamination is oriented perpendicular to the film and source it will not be detected due to the minimal change in differential absorption.

Instruments Required:
X-ray/Gamma-ray source, radiographic film.

Time Required:
1-2 hours setup time for localized defect at each location

Skill Level:
High level of experience, ASNT certification

Advantages/Disadvantages:
Can obtain a permanent record of defect, can obtain high planar resolution of defect / requires high level of experience. This method however may record unrelated emission from outside sources.

Accuracy/Reliability:
High/Medium since planar and not volumetric characteristics are captured.

Inspection Frequency:
When required after 1st level inspection (visual/tap test)

Reverse-Geometry Digital X-Ray:

Low level X-ray imaging system which eliminates the film sheet and uses television type raster scanning combined with computer-read digital data from a detector unit which reads and writes digital images. With Reverse Geometry X-ray imaging alignment of the x-ray source, object and detector are not critical, and three-dimensional images of the defect can be constructed.

Instruments Required:
Scanning X-ray tube, point detector, computer.

Time Required:
.05-1 hour setup time for localized defect. Very slow process.

Skill Level:
Medium level of experience.

Advantages/Disadvantages:
Can obtain a high-resolution permanent 3-D digital record of defect / Units are very expensive. The process could be prohibitive in cost.

Accuracy/Reliability:
Very High/Very High.

Inspection Frequency:
Only viable in extremely important safety related circumstances

Thermography:

Uses a heat source to heat a sample surface with a light pulse, and then an infrared camera is used to measure the surface temperature response to the flash. The advantage of active thermography is that it is completely non-contacting, using remote heating and remote detection to make the measurements. Unlike UT, RT, or AE, a very high level of experience is usually not required to interpret the data; however, the equipment used can be very sophisticated. Thermography units capture and record a relatively high-resolution image of the defect as a function of pulsation flash time.

Instruments Required:
Pulse-type heat source, IR Camera.

Time Required:
.05-1 hour for setup time; scanning is instantaneous.

Skill Level:
Medium to high level of experience required.

Advantages/Disadvantages:

Can obtain a permanent record of defect, fast non-contact method, portable. IR cameras and processing unit relatively expensive; not as effective on thick composites.

Accuracy/Reliability:

High/Medium depending on image processing capability of unit.

Inspection Frequency:

When required after 1st level inspection (visual/tap test)

Shearography:

Shearography is an interferometric system that uses an expanded beam of laser light which is reflected off the specimen. Also, unlike, UT, RT, or AE, a very high level of experience is usually not required to interpret the data; however, the equipment used is very sophisticated.

Instruments Required:

Shearography unit, consisting of laser beam, shearing camera with optics, and a CCD camera.

Time Required:

.05-1 hour for setup time; scanning is rapid for local evaluation at each location

Skill Level:

Medium with advanced portable shearography unit.

Advantages/Disadvantages:

Fast evaluation, permanent defect record. / Difficult to detect internal defects of hollow core, expensive unit.

Accuracy/Reliability:

High (near surface)/Medium-Low depending on location of defect and type of deck.

Inspection Frequency:

When required after 1st level inspection (visual/tap test)

Load Test Method:

Loads are placed on the structure and the response of the structure is measured by using instrumentation. Unusual deck behavior characterizes the likelihood of potential problems.

Instruments Required:

Load source (usually water truck/tankers), array of sensors (i.e. strain gauges, displacement sensors, and accelerometers), Multi-channel data acquisition system.

Time Required:

1 day for setup and testing of reference bridge.

Skill Level:

High level to setup and reduce load test data.

Advantages/Disadvantages:

Can quickly determine if bridge deck is experiencing larger deflection due to loss in the stiffness of the structure. Cannot isolate location of damage.

Accuracy/Reliability:

Medium/Medium, does not isolate or determine nature of damage. However very effective to screen structure for stiffness loss.

Inspection Frequency:

Recommended at end of construction, and repeated during in-depth inspection.

3.0 APPLICABILITY OF INSPECTION METHODS TO MAJOR DECK TYPES

This section summarizes application of NDE inspection methods for specific manufactured deck types.

1. Manufacturer: Kansas Structural Composites.

Deck type: Sandwich-type construction composed of a deep center core system with top and bottom face sheets bonded to the center core. The center core is made of vertically placed corrugated glass panels bonded together.

Inspection Method	What type of defects can be detected?	What type of defects cannot be detected?	Notes
Visual	Wear/degradation or delamination of top/bottom face sheet, blisters, impact cracks, freeze/thaw cycling damage, crazing, holes in the panel/crushed panels	Subsurface defects masked by the overlay, internal defects, internal voids	1, 2, 5
Tap Test	Delamination of the wear surface, delamination of the face sheets from the core, crushed core, impact damage.	Internal defects in the hollow corrugated core	1, 2, 4
Ultrasonic	Delaminations, disbonds, resin variations, broken fibers, impact damage, moisture, cracks, voids, and subsurface defects.	Difficult to detect defects in the thin corrugated vertical panels from the top or bottom	6, 7
Acoustic Emission	Global monitoring to direct conventional NDE methods to the localized problem areas that contain defects, defect growth rate.	Defect configuration, type or size.	6
Thermography	Delaminations, disbonds, impact damage, moisture, and voids in the top and bottom face sheets.	Defects in the hollow corrugated core	3, 5, 7
Shearography	Delaminations, disbonds, impact damage, and voids in the top and bottom face sheets.	Defects in the hollow corrugated core	3, 5, 7
Radiography	Some delaminations and some disbonds depending on the orientation, voids, resin variations, broken fibers, impact damage, and cracks.	Planar defects which are oriented perpendicular to the source.	6, 7
Reverse-Geometry Digital X-Ray	Delaminations, disbonds, resin variations, broken fibers, fiber placement, impact damage, moisture, cracks, voids, defects in the core, real time 3D image.	Virtually none provided collector and source can be indexed together.	3, 6, 7
Load Test Method	Stiffness change in deck due to degradation.	Defect configuration, location, type or size	6

2. Manufacturer: Infrastructure Composites Inc.

Deck type: Same as KSC.
Inspection Method Matrix: Same as KSC.

3. Manufacturer: Hardcore Composites Inc.

Deck type: Sandwich type construction composed of a solid core system with top and bottom face sheets bonded to the center core. The center core is made of vertically standing foam forms wrapped in glass cloth and arranged in an array.

Inspection Method	What type of defects can be detected?	What type of defects cannot be detected?	Notes
Visual	Wear/degradation or delamination of top/bottom face sheet, blisters, impact cracks, freeze/thaw cycling damage, crazing, holes in the panel/crushed panels	Subsurface defects masked by the overlay, internal defects, internal defects in the solid core	1, 2, 5
Tap Test	Delamination of the wear surface, delamination of the face sheets from the core, crushed core, impact damage.	Most internal defects in the solid core	1, 2, 4
Ultrasonic	Delaminations, disbonds, resin variations, broken fibers, impact damage, moisture, cracks, voids, and subsurface defects.		6, 7
Acoustic Emission	Global monitoring to direct conventional NDE methods to the localized problem areas which contain defects, defect growth rate.	Defect configuration, type or size.	6
Thermography	Delaminations, disbonds, impact damage, moisture, and voids in the top and bottom face sheets.	Defects imbedded deep in the solid core	3, 5, 7
Shearography	Delaminations, disbonds, impact damage, and voids in the top and bottom face sheets.	Defects imbedded in the solid core, delaminations with in the solid core.	3, 5, 7
Radiography	Some delaminations and some disbonds depending on the orientation, voids, resin variations, broken fibers, impact damage, and cracks.	Planar defects which are oriented perpendicular to the source.	6, 7
Reverse-Geometry Digital X-Ray	Delaminations, disbonds, resin variations, broken fibers, fiber placement, impact damage, moisture, cracks, voids, defects in the core, real time 3D image.	Virtually none provided collector and source can be indexed together.	3, 6, 7
Load Test Method	Stiffness change in deck due to degradation.	Defect configuration, location, type or size	6

4. Manufacturer: Martin Marietta Composites Inc.

Deck type: Continuous hollow pultruded trapezoidal sections.

Inspection Method	What type of defects can be detected?	What type of defects cannot be detected?	Notes
Visual	Wear/degradation, blisters, impact cracks, freeze/thaw cycling damage, crazing, holes in the panel/crushed panels	Subsurface defects masked by the overlay, internal defects, internal defects in the solid core	1, 2, 5
Tap Test	Delamination of the wear surface, crushed web, impact damage, lap joint debonding.	Internal defects in the web.	1, 2, 4
Ultrasonic	Resin variations, broken fibers, impact damage, moisture, cracks, voids, lap joint debonding.	Difficult to detect defects in the web.	6, 7
Acoustic Emission	Global monitoring to direct conventional NDE methods to the localized problem areas which contain defects, defect growth rate.	Defect configuration, type or size.	6
Thermography	Impact damage, moisture, and voids in the top and bottom of the trapezoidal section, lap joint debonding.	Defects in the web.	3, 5, 7
Shearography	Impact damage, and voids in the top and bottom of the trapezoidal section, lap joint debonding.	Defects in the web.	3, 5, 7
Radiography	Voids, resin variations, broken fibers, impact damage, and cracks.	Planar defects which are oriented perpendicular to the source.	6, 7
Reverse-Geometry Digital X-Ray	Resin variations, broken fibers, fiber placement, impact damage, moisture, cracks, voids, defects in the core, real time 3D image, lap joint debonding.	Virtually none provided collector and source can be indexed together.	3, 6, 7
Load Test Method	Stiffness change in deck due to degradation.	Defect configuration, location, type or size	6

5. Manufacturer: Creative Pultrusions Inc.

Deck type: Continuous hollow pultruded hexagonal sections bonded to form the deck.
Inspection Method Matrix: Same as MMC.

6. Manufacturer: Strongwell.

Deck type: Sandwich type construction consisting of hollow pultruded double-web beams bonded together as the core with a top and bottom laminate face sheets.

Inspection Method	What type of defects can be detected?	What type of defects cannot be detected?	Notes
Visual	Wear/degradation or delamination of top/bottom face sheet, blisters, impact cracks, freeze/thaw cycling damage, crazing, holes in the panel/crushed panels	Subsurface defects masked by the overlay, internal defects, internal voids	1, 2, 5
Tap Test	Delamination of the wear surface, delamination of the face sheets from the core, impact damage.	Internal defects in the hollow pultruded double-web beam	1, 2, 4
Ultrasonic	Delaminations, disbonds, resin variations, broken fibers, impact damage, moisture, cracks, voids, and subsurface defects.	Difficult to detect defects in the hollow pultruded double-web beam	6, 7
Acoustic Emission	Global monitoring to direct conventional NDE methods to the localized problem areas which contain defects, defect growth rate.	Defect configuration, type or size.	6
Thermography	Delaminations, disbonds, impact damage, moisture, and voids in the top and bottom face sheets.	Defects in the web section of the hollow pultruded double-web beams	3, 5, 7
Shearography	Delaminations, disbonds, impact damage, and voids in the top and bottom face sheets.	Internal defects in the hollow pultruded double-web beam	3, 5, 7
Radiography	Some delaminations and some disbonds depending on the orientation, voids, resin variations, broken fibers, impact damage, and cracks.	Planar defects, which are, oriented perpendicular to the source.	6, 7
Reverse-Geometry Digital X-Ray	Delaminations, disbonds, resin variations, broken fibers, fiber placement, impact damage, moisture, cracks, voids, defects in the core, real time 3D image.	Virtually none provided collector and source can be indexed together.	3, 6, 7
Load Test Method	Stiffness change in deck due to degradation.	Defect configuration, location, type or size	6

Notes: 1.1st level global screening, 2.Low cost. 3.High equipment cost 4.Low level of experience required
5. Medium level of experience required. 6.High level of experience required
7. Method to evaluate detected localized damage/defects after 1st level screening or AE.