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Adhesively Bonded Composite Repairs of Oil and Gas Structures

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ABSTRACT

Repair of degraded structural members with substantial corrosion damage is a critical job of structural integrity management of oil and gas structures for both offshore and onshore. Conventionally cutting and welding repairs of damaged/corroded structure members are generally used in the industry and allowed from regulatory requirements. However, such repair method is considered as a hot work repair method. Once the hot work repair is planned, there is the safety requirement that the subject tank/location and adjacent tanks be in a gas free condition. In such cases, it may cause a significant impact on the continuous operation of the units.

Therefore, adhesively bonded composite repairs of damaged/corroded steel structures have been increasingly used for onshore and offshore oil and gas structure repairs due to favorite considerations of safety and continuous operation as the repairs can be done without cutting and welding. The repair method utilizes a new steel plate bonded to the existing damaged/corroded steel plate by specially selected adhesive polymer(s), known as sandwich composite plate repair technology. The repair can be done from one side of the structure to be repaired and the other side of the structure would remain unaffected during the repair. This paper introduces the bonded sandwich plate repair technology and requirements/recommendations from classification and industry standards/guidelines on the bonded composite repairs of steel structures.

Key words: corrosion, sandwich plate, composite repair

INTRODUCTION

Both onshore storage tanks and offshore/marine vessels and units (such as floating production storage and offloading (FPSO) units, Floating Storage and Offloading (FSO) units) for oil and gas drilling,

Reduction of Conservatism in Ssc Testing for Sour Gas Well Tubulars

production, and transportation generally experience very corrosive environments. Even some corrosion prevention systems, such as applicable cathodic protection, protective coatings, and/or liquid/vapor phase inhibitors, are usually used for corrosion protection, severe corrosion to the structures still happens due to lack of corrosion protection and corrosion management. Repair of degraded structural members with substantial corrosion damage is critical to maintain structural integrity for safety and continuous operation.

Conventionally crop-and-replace repair method by cutting and welding is generally used in the oil and gas industry and allowed from regulatory requirements. However, these repairs are considered as a hot work repair method, which is a considerable safety concern for oil and gas operations (drilling, production, and storage). Once the hot work repair is planned, it is necessary that the subject tank/location and adjacent tanks are in a gas free condition from the safety requirements. In such cases, it may cause a significant impact on the continuous operation of the units.

Safety and cost-effective solutions are the driving force for consideration of non-hot work repair method. Thus, composite repairs by using a new steel plate adhesively bonded to existing steel structure are generally preferred for favorite considerations of safety and continuous operation as the repairs can be done without cutting and welding. With the increased use of composites in repairs of oil and gas, more performance data and better repair practices are available and have built up confidence in developing better industry standards. This paper introduces composite repair technologies and requirements/recommendations from classification and industry standards/guidelines on the adhesively bonded composite repairs for steel structures. Some use cases from nearly 20 years of experience in use of steel-elastomer-steel sandwich composite plate, also known as Sandwich Plate Structure (SPS), are provided as examples in this paper.

REQUIREMENTS AND RECOMMENDATIONS

Acceptance of adhesively bonded composite repair method for corroded steel structures and piping as alternative method of steel / piping replacement is determined based on many factors. Those factors may include type and severeness of structure damage to be repaired, structure member service environment, repair environment, and expected repair life. They may also include use of qualified repair technologies, proved repair process from the technology service provider, qualification of repair installer, in addition to qualification of materials and material handling/storage. Some limited industry standards and class recommendations on adhesively bonded composite repair are available as industry guidelines.

Current standards and recommendations on adhesively bonded composite repairs from major class societies are as following:

Class society ABS has newly developed the first 2019 version of *Guidance Notes on Composite Repairs of Steel Structures and Piping*,¹ primarily for applications on the site-specific offshore structures. Those guidance notes provide guidelines on the bonded composite repairs of steel structures and piping with detailed consideration of all repair stages from damage assessment, repair design, personnel qualification, materials and test, installation, and inspection/testing. The appendix of the guidance notes is dedicated to sandwich plate repair.

Class society BV provides a *Guidance Note NI 613 on Adhesive Joints and Patch Repair* on adhesive bonding system design, assessment, and testing.² A simple guideline on adhesively bonded composite patch repair for corroded area or crack is provided for non-structural patch repair. The guidance note does not intend to apply to hull girder members.

Class society Lloyd's Register (LR) developed *Provisional Rules for the Application of Sandwich Panel Construction to Ship Structure*, in conjunction with the sandwich composite plate structure technology,

for both new constructions and repairs.³ The sandwich composite plate structure technology is a technology in which two metal plates are bonded to a solid elastomer core (Figure 1). The elastomer core provides continuous support to the plates and is intended to stop buckling and reduce the need for stiffeners. The sandwich composite plate structure technology is also used for various structural repair projects since 1999. About 340 repair projects have been completed for various structural repairs of ships and offshore units.

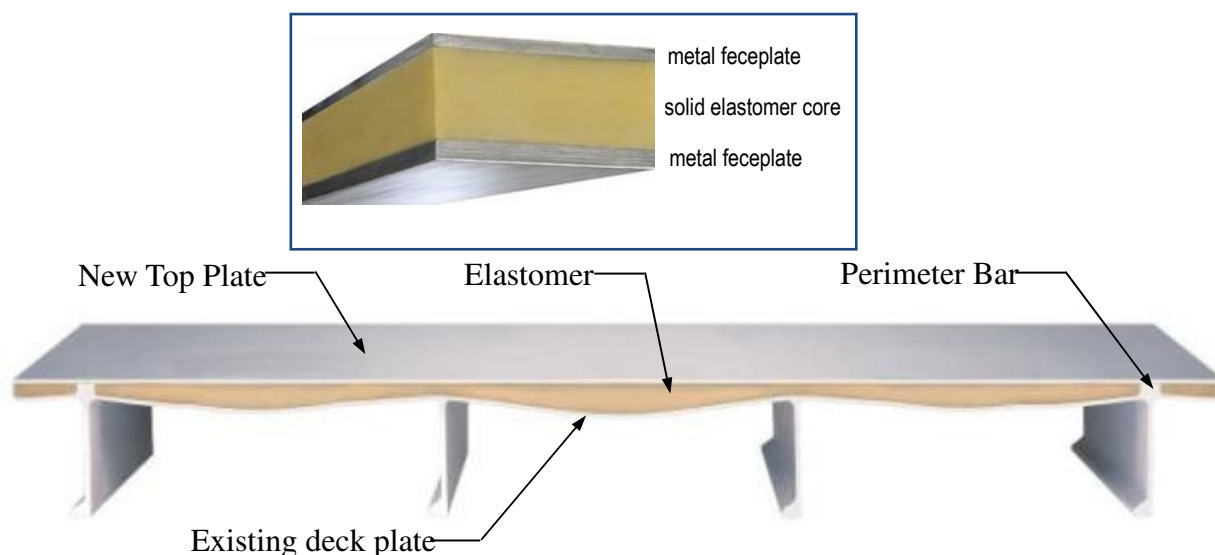


Figure 1. Typical Sandwich Plate Repair

Another class society, DNV-GL, has a comprehensive set of rules/recommendations on composite construction and repair of steel structures, such as

- a) *Class Guideline DNVGL-CG-0154 on Steel Sandwich Panel Construction* for both new constructions and repairs,⁴
- b) *Recommended Practice DNVGL-RP-C301 on Design, fabrication, operation, and qualification of bonded repair of steel structures*, covering from damage assessment, repair design making, repair design, material qualification/testing, repair installation and in-service survey/inspection,⁵ and
- c) *Offshore Standard DNV-OS-C501 on Composite Components* providing requirements and recommendations for structural design and structural analysis procedures for composite components, which is useful for composite patch design and qualification of adhesively bonded composite patch.⁶

Due to complexity of the composite repair from various material properties and configurations, there is uncertainty from engineering calculations due to lack of accurate material test data reflecting the long-term and short-term properties after repairs. Because of such complexity, this paper will focus on adhesively bonded sandwich steel (steel or other metal patch) plate repair technology, not on adhesively bonded sandwich composite (Fiber Reinforced Plastic (FRP) patch) repair. Substrate material can be steel or aluminum, not FRP.

CORROSION DETERIORATION AND REPAIR CRITICALITY

Examination of the corrosion deterioration and damages shall be done before repair proposal is made. Repair decision should be made if the unit's fitness is impaired or if there is a chance to affect the

structural fitness or watertight integrity of the unit later due to the extent and severity of the structural deterioration under the intended service conditions.

The examination should include

- Location and extent of the structural deterioration or damage with drawings and photographs/video
- Thickness gauging data
- Service conditions such as operating pressure, temperature, type of fluid/cargo
- Possible cause of the structural deterioration
- Description of accessibility to the location for repairs and further inspection/monitoring

Once examination information is available, the damage criticality should be evaluated, and repair criticality should be determined based on the damage criticality and structural element criticality. The structural element criticality can be critical structural element or non-critical structural element according to definitions from applicable class Rules and regulations. The damage criticality is evaluated based on criteria from applicable rules or regulations. For example, a steel plate shall be replaced if the steel plate remaining thickness is less than 70% of as-built thickness. The repair decision on the repair criticality should be made from the decision-making process such as:

- a) If the degraded element is a non-critical element, such element repair is considered non-critical.
- b) If the degraded element is a critical element but the extent and sizes of the degradation are not substantial and within allowable limits from the criteria defined by applicable class rules or regulations, the any repair to such the degraded element is considered non-critical.
- c) When the corrosion deterioration of a critical element is more than allowable limits from the criteria defined by applicable class rules or regulations, steel renewal may be required, and such repair is considered critical. Any corrosion associated with wastage over the allowable limits or extensive areas of wastage over the allowable limits which would affect the unit's structural, watertight, fire integrity and/or weathertight integrity should be promptly and thoroughly repaired.

Non-critical repairs can be done by adhesively bonded steel sandwich without detailed engineering design and analysis. When the bonded steel sandwich repair method is considered in lieu of steel structure replacement of a critical element, detailed global or local strength calculations using approved repair design and materials may be needed. ABS Class does not allow a bonded composite repair for critical class structural elements with complete thickness loss except for localized pitted holes, provided that the repair criticality is assessed.¹

Cracks may often be considered critical. Adhesively bonded sandwich steel plate repairs may be considered inappropriate for critical fatigue cracks. For non-critical fatigue cracks, adhesively bonded sandwich repairs may be used to slow down fatigue crack propagation. However, the repair life is not predictable and constant monitoring may be needed to ensure the crack does not grow.

REPAIR DESIGN

The bonded sandwich steel plate repair is to restore the functions of the original structural component, such as functions of load capacity, wear / impact resistance, stiffness, dimensional stability, fluid/cargo containment and tightness, electrical resistance, electrochemical properties, vibration, and fire/explosion resistance.

Degradation of the adhesive may lead to premature failure of the repair. The design should consider and verify that the composite repair is suitable for the intended operating environment. Service