PERFORMANCE AND LOCAL DAMAGE IMPROVEMENT AROUND AIR VALVE IN AQUEDUCT BRIDGES

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1. Introduction

The importance of aqueducts has gained wide acceptance in the water transportation manufacturing business over time. It has been specified in the guidelines such as the design criteria of water supply facilities. A substantial amount of experimental research has been conducted on pipelines; however, repaired pipelines have not been known well about their performance. Despite the fact that most pipeline repairs and retrofitting are frequently made by the insertion of a steel liner and welding them collectively, or if convenient, by the use of external steel sleeve elements; despite that, fiber-reinforced polymers (FRP) are quickly obtaining popularity as a replacement rapid repair method. This study considered the repair method of the air valve on the aqueduct bridge and its effect by FEA, referring to the accident at the Musota aqueduct bridge.

2. FEM model and verification

The numerical model is implemented by the commercial package Abaqus/CAE 2022 was used. A pipe material presented in Table 1 was used in all the models. The pipe is a typical Grade SS400 spec steel pipe, with the material properties mentioned in Table 1 including the FRP properties as retrofitting material. The pipe was initially modeled completely and partitioned in the areas of defects and prone to damage, considering the advantage of the double symmetry to mitigate the execution time of analysis. Table 2 and figure 1 show three different cases of the FE model for air valve retrofitting the existing model, With FRP sheet and FRP wrapping.

Table 1 Pipe steel and FRP specification

Steel	
Type	SS400
Young's Modulus (MPa)	205
Poisson's Ratio	0.29
Minimum Yield Stress (MPa)	235
Tensile Strength(MPa)	400
FRP	
Young's Modulus E l (GPa)	55
Young's Modulus E2 (GPa)	15.2
Young's Modulus E3 (GPa)	15.2
Poisson's Ratio ν12	0.254
Poisson's Ratio ν13	0.254
Poisson's Ratio ν23	0.428
Shear modulus G12 (GPa)	4.7
Shear modulus G13 (GPa)	4.7
Shear modulus G23 (GPa)	3.28

Table 2 Model cases

Case 1	Existing model
Case 2	FRP Sheet
Case 7	FRP Wrapping

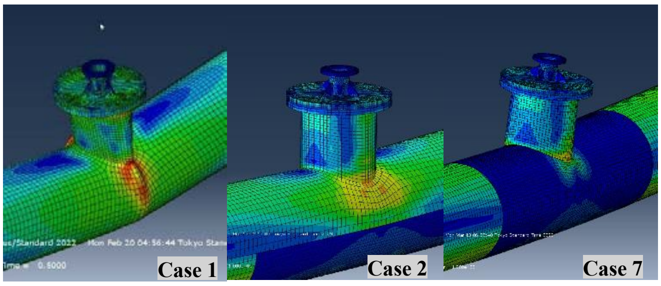

Fig.1 FE model cases for air valve retrofitting; Case1: Existing model, Case2: With FRP sheet, Case3: FRP wrapping

Very fine meshing, using Abaqus's 8-node linear brick element, C3D8R, was used to model the cases of retrofitting. A typical mesh is shown in Figure 3. The composite layer was modeled by combining the composite layup feature of the Abaqus applied to C3D8R solid element. The boundary conditions were implemented by defining reference points at each end of the pipes, alongside the longitudinal axis. The reference nodes were fixed in all translations and

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rotations excluding the longitudinal translation and the rotational degree of freedom corresponding to the implemented gravity force. It can be confirmed that the deformation shape is similar to that shown in figures 2 and 3, which is a camera image of the collapse of the aqueduct pipe.

Fig.2 Wakayama aqueduct bridge failure

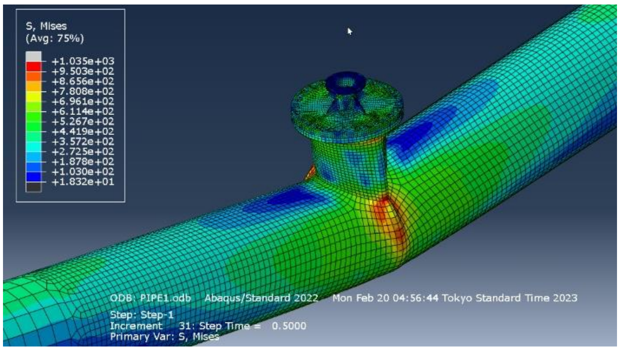

Fig.3 FEM model local damage verification of water transmission pipeline

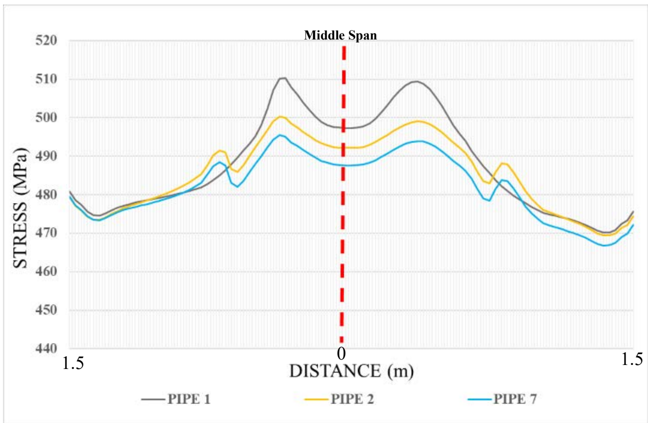

Fig.4 Stress variation within the pipe external region in the steel.

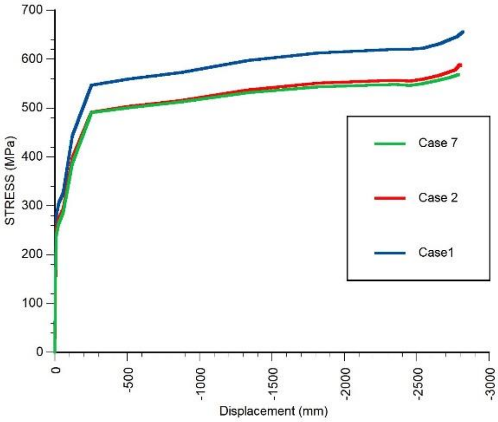

Fig.5 FRP sheets, and wrapping and Stress displacement of middle span in different cases

The maximum stress state of the pipe at this time was approximately 510 MPa on the tensile and -660 MPa on the compressive side. Therefore, under the condition that the pipe fails in addition to the breaking condition of the suspension material of the bridge, bending and local damage occurs at the middle span where the air valve is located. Therefore, by using FRP material as a secondary material to retrofit the pipe at the middle span area the performance and reversibility of the pipe would be controlled by the tensile behavior of the FRP sheet. Moreover, as it is obvious from figures 4 and 5 the FRP sheets cause the steel material to reach lower stress levels at almost the same displacement of the middle span and there is a direct relation between improving performance and limiting the stress in the steel pipe by using composite sheets.

3. Results

In this study, the behavior of FRP-retrofitted pipes under bending due to gravity conditions is investigated. As expected, in such retrofitting conditions; pipes, in the middle-span zone would endure higher damages than if the pipe was unrepaired. Strain localization in pipes under bending was prevented, and the FRP sheets increased the limited bending ability and demand of the pipes significantly. Moreover, the strain-based design could be contemplated as a viable alternative for pipes subject to bending. Additionally, more cases are being considered, and are currently been investigated and will be reported in the future. Finally, the influence of combined loading paths, the geometry of the pipe, and the air valve location should also be investigated.

