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Test rig development for load test of pipe saddle support

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ABSTRACT

Pipe saddle support is a structure commonly used to support horizontal steel pipe. It prevents direct contact between the pipe and the support. Pipe saddle support can experience displacement due to pipe movement and insufficient stress analysis. Given these concerns, conducting a load test is essential to determine the stress on pipe saddle supports. However, a universal testing machine (UTM) is not suitable for this purpose due to the size limitation. Therefore, this study proposed a test rig setup for the pipe saddle support load test. The test rig consists of a portal frame secured by an underground locking system featuring a strong floor. Additionally, an actual pipe is utilized to replicate actual loading conditions on the pipe saddle support. The applied load is measured using a load cell, with a custom-designed bracket to ensure precise load transfer. Finally, the pipe saddle support specimen is bolted to a base support to maintain stability during the load test. Stress analysis using finite element analysis (FEA) demonstrated that the test rig is suitable for conducting load tests on the specimens with a maximum force of 80 kN. FEA confirmed that the test rig operates within a safety factor of 1.3.

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1. INTRODUCTION

The pipe saddle support is a structure commonly used to support horizontal steel pipes from beneath [1]–[3]. It functions by transferring loads from adjacent structures, thereby preventing direct contact between the pipe and the support [4]. Pipe saddles are typically used when additional structural support is required at the attachment point between the slipper and the pipe [5].

However, in the case study by Nuthanapati *et al.* [6], several issues related to pipe saddle support were identified. Pipe saddle support can experience displacement due to the pipe's sudden movement and insufficient stress analysis. As a result, the failure of the pipe rack structure becomes an inevitable outcome. Additionally, there is a lack of standardized procedures for pipe saddle support design and analysis [7]. Given these concerns, load testing is essential to determine the stress distribution of pipe saddle supports and is also necessary to ensure the safety of the pipe saddle support [8], [9].

A load test can be performed with a universal testing machine (UTM). However, the UTM is designed for standard-shaped specimens. The Shimadzu AGX-V2 series, for instance, accommodates optimal specimen sizes up to 790 mm or 31 inches. In comparison, pipe sizes used in the oil and gas industry can range up to 48 inches, making them unsuitable for testing with a UTM. Furthermore, to perform a load test for pipe saddle support, it required an actual pipe was required for a more accurate experiment result.

Research on pipe supports has shown that custom test rigs are often built to meet specific testing requirements [10], [11]. Moreover, due to practicality and cost effectiveness, performing a load test on scaled models is considered to validate the full scaled design [12]. A test rig for a large-scale 3-dimensional test frame was developed in a study [13], while the majority of previous studies only provided tests for a 2-dimensional frame. Another study [14] used a custom setup to match the boundary conditions and applied a load to the specimen.

Test rigs must be rigid and strong enough to ensure they do not influence the test results [15], [16]. Studies on test rig development have used safety factors ranging from 1.25 to 3, depending on the rig's size. This safety factor is chosen to ensure that the test rig was not overloaded during the load test [17]–[19]. These studies offer valuable insights into the fabrication of test rigs. However, they do not present a setup specifically designed for testing pipe saddle support specimens.

This study aims to develop a test rig for conducting load tests on pipe saddle support specimens, with the goal of providing greater flexibility to accommodate pipe saddle supports with sizes up to 48 inches. This test rig is intended to handle load tests for pipe saddle support with capacities up to 80 kN. An actual pipe will be used to provide an actual loading condition to the pipe saddle support specimen. Moreover, finite element analysis (FEA) will be performed prior to fabrication to enhance confidence for predicting the stress [20]–[23]. FEA will be performed on each individual component to simplify the analysis of the test rig [24]. The purpose of this study is to provide an accurate and reliable method of performing a load test for pipe saddle support.

2. RESEARCH METHOD

Figure 1 presents a research process flowchart that shows the development process for the load test of the pipe saddle support. Pipe saddle support model was designed using computer-aided design (CAD) software. Once the model's design and the maximum load are confirmed, the test rig will be designed with a capacity of the model's maximum load.

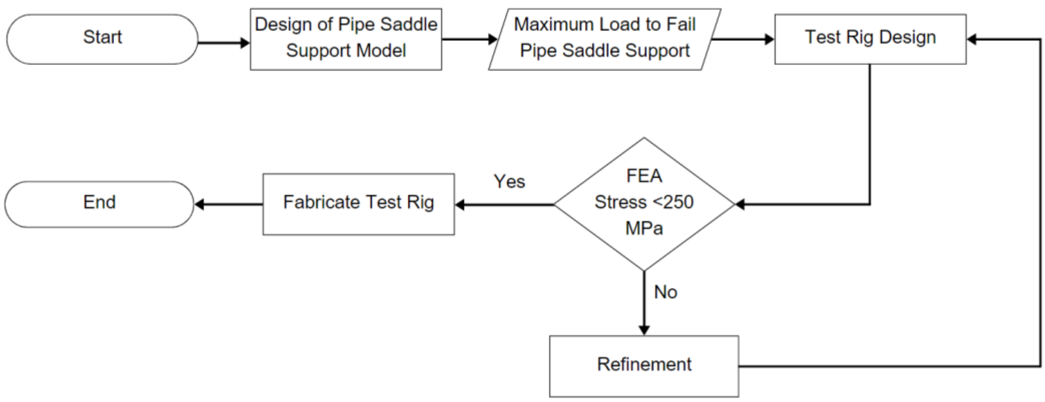


Figure 1. Flowchart diagram of pipe saddle support load test rig study

2.1. Pipe saddle support test rig requirements

Figure 2 illustrates the pipe saddle support model that will be tested. For this study, the pipe saddle support features a 6-inch inner diameter, with all the plate thicknesses being 2 mm. The components of the pipe saddle support are connected by welded joints. Furthermore, in industrial applications, pipe saddle supports are positioned on top of pipe racks while the saddle plate cradles the pipe. To test with these conditions, the base plate of the pipe saddle support should be bolted to the corresponding support base. Moreover, an actual pipe is used to apply the load on top of the saddle plate.

On the other hand, FEA was conducted to assess the load to fail the model. Failure is defined when the model's Von Mises stress exceeds the material's yield strength of 250 MPa. Figure 3 illustrates the fixed support and the method for applying load on the model. It shows that the downward force is directly applied to the saddle plate while the base plate acts as a fixed support. FEA indicated that a force of 80 kN is required to induce failure in the pipe saddle support model. Additionally, for this study, stress values of the test rig should not exceed 200 MPa to maintain a safety factor of 1.25. Complying with this safety factor is important to increase the safety of the operator and ensure it does not affect the accuracy of the results.

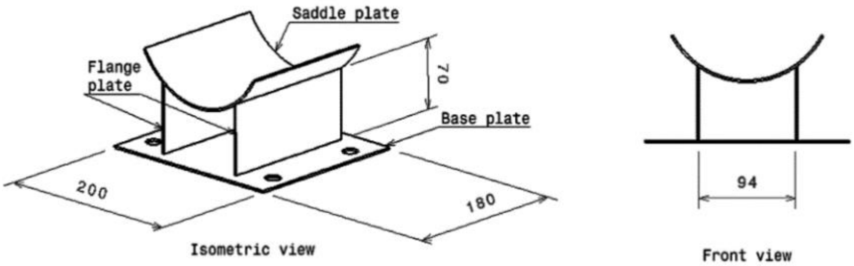


Figure 2. Pipe saddle support model

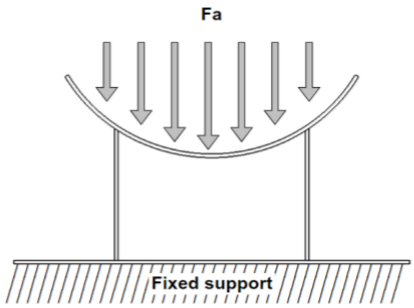


Figure 3. Boundary condition of the pipe saddle support model

2.2. Setup of pipe saddle support test rig

A portal frame is commonly used for a structural test rig, either static or dynamic load test [25]–[28]. In this study, the portal frame consists of a column, a beam, and a flat bar. The I-beam type is used for the column and beam to provide structural rigidity to the structure, considering the large load required to fail the specimen. The portal frame is secured by the underground locking system, as shown in Figure 4. This system features a strong floor, flat bar, stud, and lock plate. The experiment setup conducted by Tanghetti *et al.* [29] provides an I-beam that is locked to the strong floor for shear platform testing. The I-beam that was attached to the strong floor was set to freely move horizontally. In comparison, this study provides a fixed movement for the I-beam, either horizontal or vertical, due to the purpose of the test, which is a static load test. Additionally, this portal frame is equipped with a hydraulic system for applying load to the specimen. The second section of the test rig is designed to support the specimen. It contains a support base to securely place the specimen. The specimen will be bolted to this support base to ensure stability throughout the testing process. Lastly, the third section of the test rig is designed to apply a load to the pipe saddle support. It consists of a pipe that rests directly on top of the saddle plate. A load cell bracket is positioned on top of the pipe to distribute the load from the load cell to the pipe. Figure 5 presents overall test rig design of the setup.

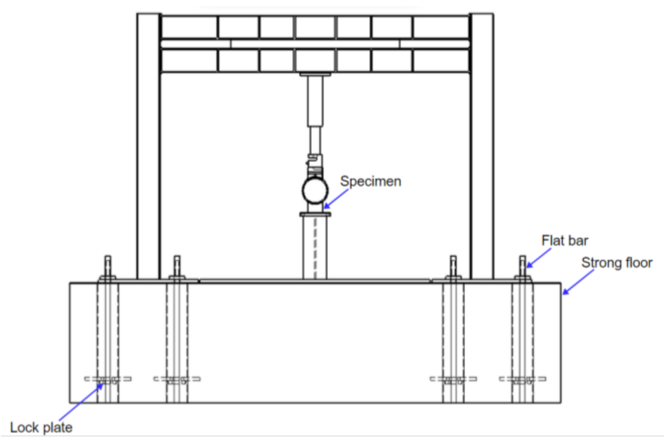


Figure 4. Underground locking mechanism of the test rig

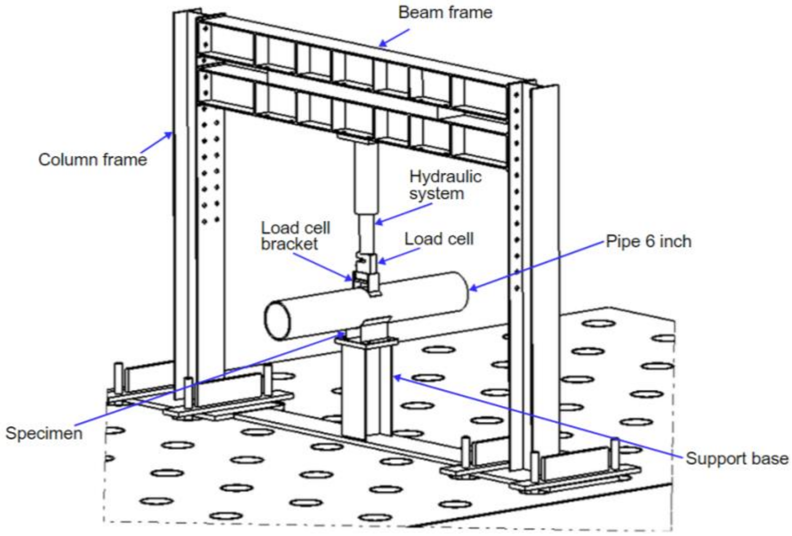


Figure 5. Test rig overall setup

2.3. FEA of test rig components

Following the setup of the test rig, the load flow for each component is defined and illustrated in Figure 6. This flow corresponds to the maximum load required to cause failure in the model. The load distribution is influenced by the positioning and the total number of components in the test rig. The flow originates from the hydraulic system, which applies force to the pipe and specimen. Additionally, it exerts force on the portal frame and the lock plate, which serves as the underground locking system. Table 1 summarizes the applied loads (Fa) and the number of test rig components.

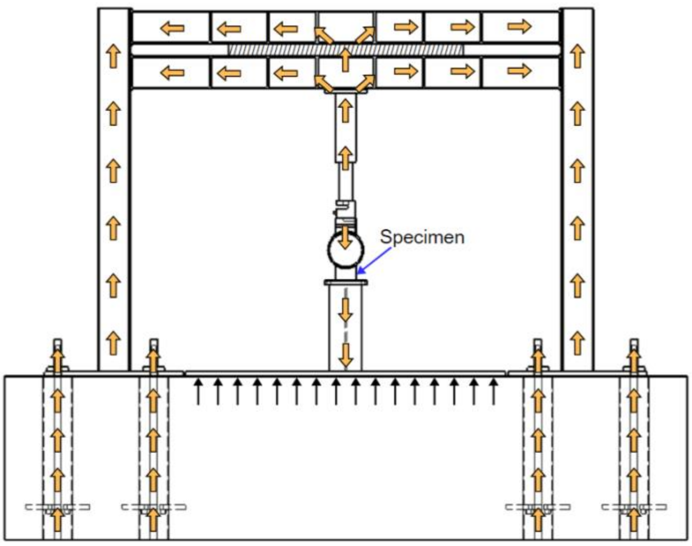


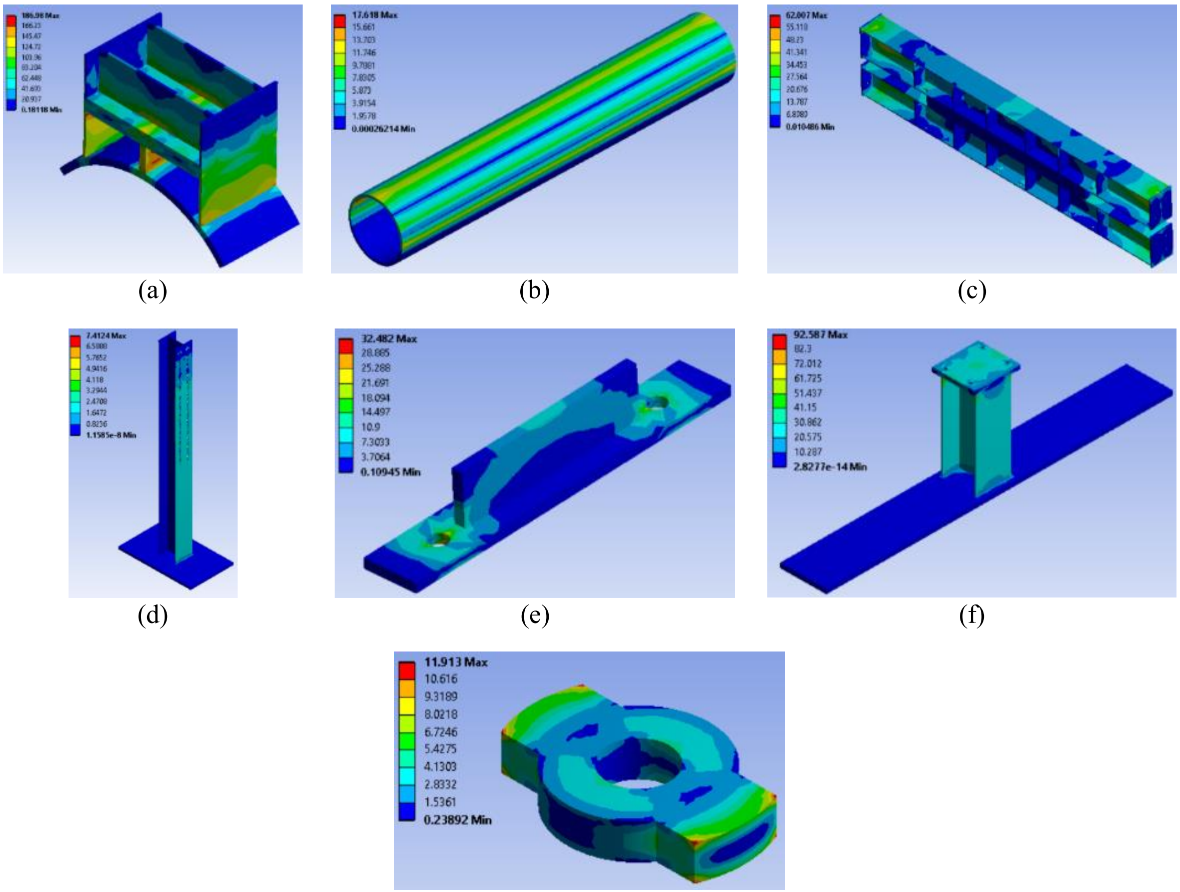
Figure 6. Test rig load flow

Table 1. Number of components and applied load to the test rig

No	Parts	Number of components	Fa (kN)
1	Load cell bracket	1	80
2	Pipe 6 inch	1	80
3	Double beam frame	1	80
4	Column frame	2	40
5	Flat bar	4	20
6	Support base	1	80
7	Lock plate	8	10

3. RESULTS AND DISCUSSION

Once the load flow is established, FEA of each component is performed. FEA results evaluate the Von Mises stress experienced by the components. Von Mises stress distribution of each test rig components is illustrated in Figure 7 with load cell bracket in Figure 7(a), Pipe 6 inch in Figure 7(b), beam frame in Figure 7(c), column frame in Figure 7(d), flat bar in Figure 7(e), base support in Figure 7(f), and lock plate in Figure 7(g).



(a) (b) (c)

(d) (e) (f)

(g)

Figure 7. FEA result for each of the test rig components of (a) load cell bracket, (b) pipe 6-inch, (c) beam frame, (d) column frame, (e) flat bar, (f) base support, and (g) lock plate

FEA was conducted to obtain the Von Mises stress of the test rig while the required load is applied. Von Mises stress, along with the safety factor, is presented in Table 2. It shows that all of the components of the test rig are experiencing Von Mises stress under the material's maximum yield strength, which is 200 MPa. Additionally, the safety factor of the test rig, exceeding 1.25 as recommended by several studies [17]–[19], falls within the acceptable range. Hence, the test rig is competent in conducting pipe saddle support load tests with a maximum force of 80 kN, without exceeding its stress limit or compromising the test results. An image of the fabricated test rig and its components is shown in Figure 8.

Table 2. Von Mises stress and safety factor of the test rig components

No	Parts	σ_v Von Mises stress (MPa)	σ_y Yield strength of mild steel (MPa)	Safety factor
1	Load cell bracket	186	250	1.3
2	Pipe 6 inch	17.6		14.2
3	Beam frame	62		4.0
4	Column frame	118.6		2.1
5	Flat bar	32.5		7.7
6	Support base	92.6		2.7
7	Lock plate	47.7		5.3

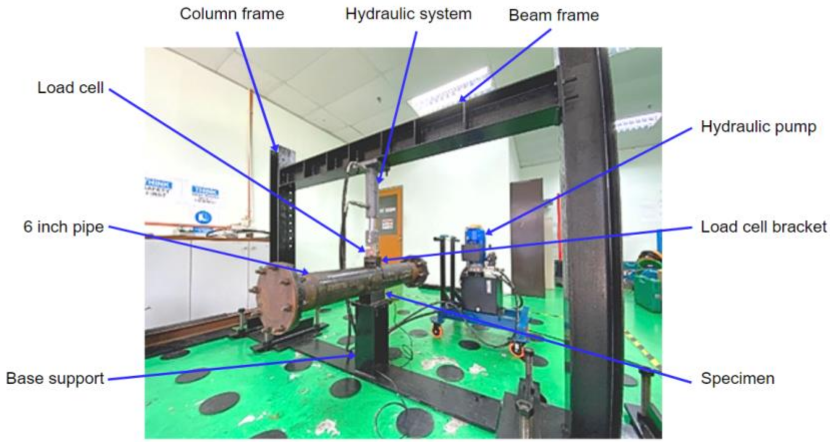


Figure 8. Test rig set-up of pipe saddle support load test

4. CONCLUSION

This showcased the development process of the test rig for the pipe saddle support load test. This test rig consists of a portal frame that is locked to a strong floor using an underground locking system. Moreover, the test rig setup provides an actual loading condition to the pipe saddle support by using an actual pipe. FEA result indicates that the test rig satisfies the design requirements of a safety factor of 1.3. with a maximum 80 kN force. Hence, a load test can be performed safely with the proposed test rig setup. Nonetheless, this study enables an accurate load test method for the pipe saddle support specimen. Thereby, providing valuable contributions to the pipe saddle support stress analysis.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [MSY]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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