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AN EXPERIMENTAL INVESTIGATION ON BEHAVIOR OF RC PARAPET WALL OF ABUTMENT UNDER COLLISION

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ABSTRACT

Bridge damage due to pounding at joint of girders and abutments has been observed in many major earthquakes. However, the studies mainly been numerical and abutment behavior itself was rarely investigated. Very limited experimental investigations were conducted. The objective of this study is to experimentally evaluate the influence of the pounding effect on parapet wall of abutment behavior, especially on the deflection, crack and stress-strain result on parapet wall and steel reinforcement. The collision or pounding load from superstructure is idealized into incremental static horizontal load through its rupture. Results show that crack phenomenon distribute on the bottom of parapet wall, which propagate along the width of this structure. It leads the wider crack width along this parapet wall. The maximum horizontal deflection at top of this wall is 25.24 mm. In addition, the strain at the maximum crack reach the ultimate value of concrete strain, which prove by the result of developed crack, further weakening and leading to failure of the parapet wall.

Keywords: Abutment, collision, experiment, reinforced concrete, parapet wall

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1. INTRODUCTION

Generally, there are three main components of bridge construction: the deck, the superstructure, and the sub-structure which consist of abutment and piers. Abutment refers to the end support of the bridge superstructure, which transfer load from superstructure, self-weight and lateral load to its foundation. Abutment behavior, soil-structure interaction, and embankment flexibility have been found by post-earthquake reconnaissance reports to significantly influence the response of an entire bridge system under moderate to strong intensity ground motions [1].

In almost of the major earthquakes, damage of the bridge caused by pounding has been observed, e.g. the 1971 San Fernando earthquake [2], the 1999 Chi-Chi earthquake [3], and the 2004 Sumatra earthquake [4]. Observed from the damaged bridges, column failure and deck unseating caused a more serious loss. Moreover, abutment damage was also occurred due to a large portion of seismic force attracted in this structure. Its behavior has been found to significantly influence the response of an entire bridge system under strong intensity dynamic excitation [5].

An investigation on the dynamic behavior of concrete bridges with consideration of the pounding effect was studied [6, 7]. In this study [7], an analysis was focused on the seismic response of skew bridges with pounding between deck and abutment joint. It was shown that the tendency of skew bridges to exhibit transverse displacements and/or rotate (and hence unseat) after deck-abutment collision is not a factor of the skew angle alone, but rather of the plan geometry plus friction. Furthermore [6], it was confirmed that severe damage spreads over the entire parapet, the bottom of abutment and the wing wall abutment in case of impact velocity 3.0 m/s.

The collapse of the abutments is usually caused by the large stress, the soil stress or collision between adjacent decks and between deck and abutment. Furthermore, effect of collision on the behavior of abutment becomes an important aspect to be evaluated in the analysis of bridge. Previous study [8] investigated the numerical analysis on the behavior of reinforced concrete girder bridges subjected to large earthquake, especially on the behavior of abutment due to effect of collision, base-isolated pier and wing wall. From this study, it was found that initial cracking occurred at the bottom of parapet wall and spread through the parapet width.

Effect of abutment excitation on bridge pounding at joints of girders and abutments was studied experimentally [9]. This condition is so common due to the differences between the dynamic characteristics of a girder and the relatively rigid adjoining abutments. From this analysis, it was known that abutments with a stiff contact interface lead to greater pounding force and relative opening displacement than a softer contact interface. In addition, the more flexible the bridge structure, the stronger the activated pounding force.

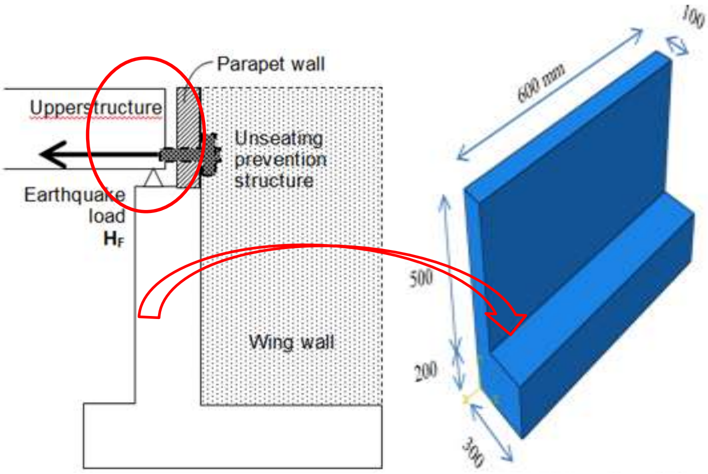
From the description above, the studies on this topic mainly been numerical and abutment behavior itself was rarely investigated. Very limited experimental investigations were conducted. The objective of this study is to experimentally evaluate the influence of the pounding effect on the abutment behavior, especially on the deflection, crack and stress-strain result on parapet wall and steel reinforcement. Abutment is simplified by the parapet wall as the upper part of this section. The collision or pounding load from superstructure is idealized into incremental static horizontal load through its rupture.

2. EXPERIMENTAL PROCEDURES

The present experimental study investigates the behavior of reinforced concrete parapet wall of abutment subjected to incremental horizontal load. A total of three RC parapet walls are tested to failure. The details of the experimental programs are presented in the following section.

2.1. Structural Modeling

The experimental program included a total of three small-scale of RC parapet wall. The details of the experimental program are given in Figure 1. The nominal dimensions of the parapet wall were 600 x 100 x 700 mm for the width, thickness and height, respectively. This structure included the support of parapet wall, with the weight of 300 mm and the thickness of 200 mm. The main reinforcement was ϕ8-100 mm and the shear reinforcement was ϕ6-100 mm.



(a) (b)

Figure 1 View of abutment, (a) Side view of abutment by Kawachi, 2019,

(b) Model of parapet wall

The material properties of concrete and steel are shown in Table 1. Concrete was designed with the compressive strength, the density and the Young modulus of 18.675 MPa, 2400 kg/m3 and 33342.61 MPa, respectively. Moreover, reinforcing bar as steel material have the density, the yield stress and Young Modulus of 7850 kg/m3, 375.3 MPa and 205939.65 MPa, respectively.

2.2. Test set-up

The parapet wall was cantilever model with fixed supported at the bottom of this structure and loaded in one incremental load, using load control by hydraulic actuator mounted horizontally in a steel frame. The deflection was measured at the top of parapet wall, which measured by means of LVDTs, as shown in Figure 2. Furthermore, the strain gauge was positioned at the reinforcement and concrete, in order to check the strain of this structure.

(a) (b) (c)

Figure 2 Static experimental set-up in laboratory; (a) hydraulic actuator, (b) position of LVDTs, and (c) reinforcement details

3. EXPERIMENTAL RESULTS

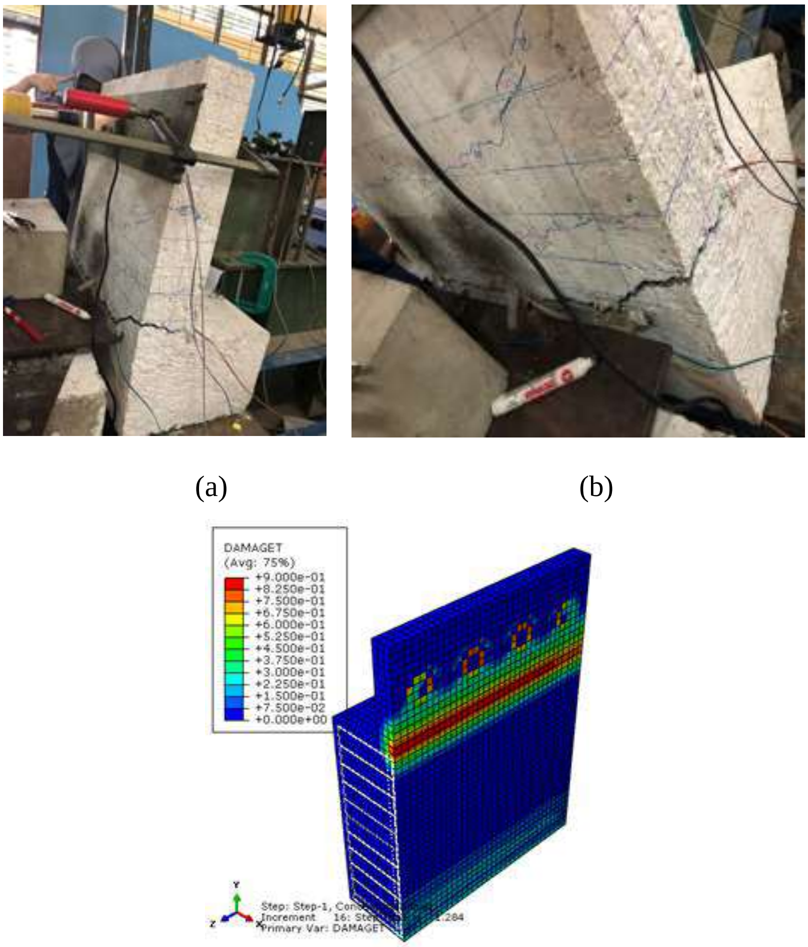
The present experimental study investigates the flexural behavior of parapet wall due to collision from the superstructure, especially on crack pattern, stress, strain, flexural moment and deflection.

3.1. Result of the Compression Test

Concrete compression test was conducted using Digital Compression Machine. The output from this test was the load history and concrete shortening which were transferred into stress and strain value. According to the result of the present compression test, it was concluded that the compressive strength of the concrete was 13.86 MPa, less than the predictable compressive strength of 18.675 MPa.

3.2. Crack pattern

In the experimental test, a typical pattern of crack formation was observed. The first flexural crack occurred in the bottom of the plate, and was followed by the formation and propagation of many smaller cracks which were distributed about the bottom of the plate and some smaller cracks in the body of this structure, as shown in Figure 3. The first flexural crack occurred at the load of 850 kg and continues to propagate at higher load levels, but the shear failure was effectively controlled by the stirrups spaced at 100 mm. The maximum resisting load was 4200 kg, which was approach the calculated critical load of this plate.



(a) (b)

(c)

Figure 3 Crack pattern and typical failure of the parapet wall; (a) and (b) propagation of the cracking, (c) contour plot of tensile damage [10]

3.3. Horizontal Deflection

The force-deflection response of the parapet wall is given in Figure 4, which was form LVDT device mounted on the top of this structure. Based on the results, it was presented that the maximum horizontal deflection occurred at the top of parapet wall was 25.24 mm.

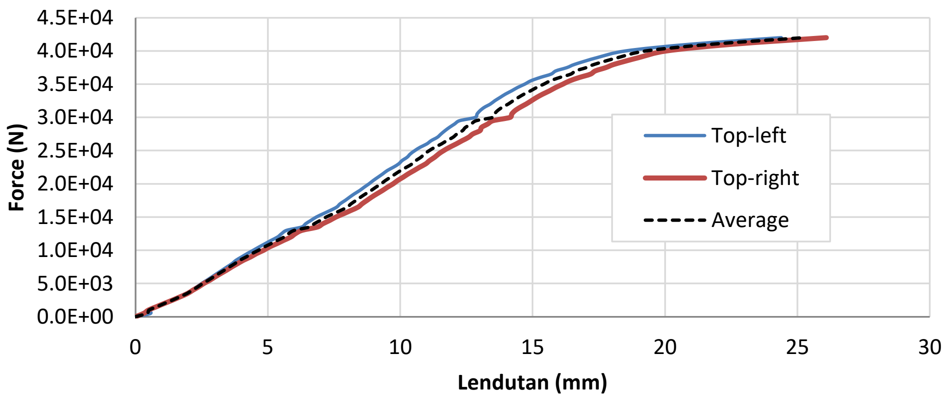


Figure 4 Force-deflection curve

3.4. Stress – Strain Distribution of the Concrete

The concrete strain is obtained from the results of the strain gauge installation on the lower part and top of parapet wall, which is shown in Figure 5 and Figure 6, respectively. According to the experimental results, it can be figured out that maximum strain at the compression side was 0.0002. In addition, the strain at the maximum crack was 0.005. Beyond the ultimate value of 0.003, the concrete is believed to fail. This condition was proved by the result of crack which was developed, further weakening and leading to failure of the parapet wall.

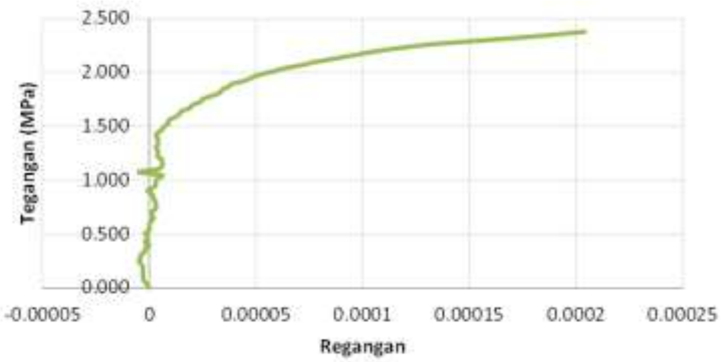


Figure 5 Stress-strain curve at the bottom part of parapet wall (compression side)

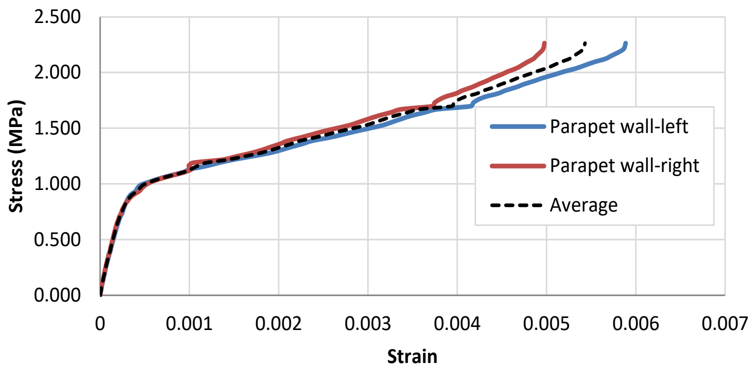
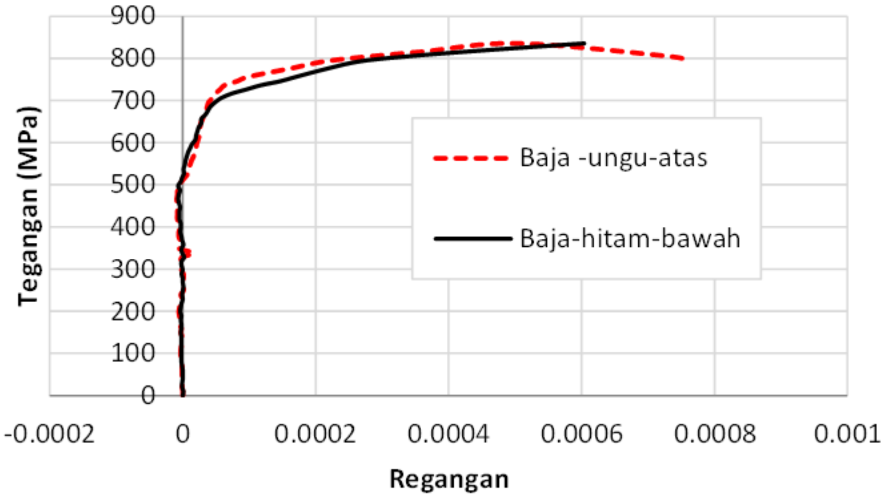


Figure 6 Stress-strain curve at top of parapet wall

3.5. Stress – Strain Distribution of the Steel

Strains that occur on the main reinforcement diameter of 8 mm are obtained from the analysis of the data on the strain gauge that is mounted on the top reinforcement, the results of which are shown in Figure 3.7. Based on the graph, it can be seen that the strain experienced by reinforcement at the top is greater than the strain that occurs in the reinforcement below it.



4. CONCLUSIONS

An experimental investigation on behavior of reinforced concrete parapet wall of abutment under collision was experimentally investigated. The collision or pounding load from superstructure was idealized by incremental static horizontal load through its rupture. The influence of the collision effect on deflection, crack and stress-strain result on parapet wall and reinforcement was analyzed.

4.1. The study reveals

1. Crack distributes on the bottom of parapet wall, with the propagation along the width this structure lead to an increase of in crack width. The maximum resisting load of 4200 kg approaches the calculated critical load of this wall.
2. Maximum horizontal deflection occurs at top of the parapet wall.
3. Strain at the maximum crack reach the ultimate value of concrete strain, which prove by the result of developed crack, further weakening and leading to failure of the parapet wall.

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