Laboratory Tests of the Area of Head Joints and Bed Joints Increase the Diagonal Shear Stress of Brick Walls

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ABSTRACT

The strength of a brick wall is influenced by the failure of the mortar bond and the resistance of the bad joint and head joint when carrying the force. The wider the head joint and bad joint areas result in a wider bonded area which increases the diagonal shear strength of the wall. Residential walls that have increased ability to withstand diagonal shear forces will be more stable when subjected to earthquake lateral forces. This research formulates that the wider the connecting area of the body and head joint, the higher the diagonal shear strength. The test was carried out by making a square test object measuring 60 x 60cm. then pressure is applied in the diagonal direction. At the time of setting up the test object is done carefully and thoroughly. The test object is positioned perpendicular to the diagonal direction. The test object is placed absolutely perpendicular and is given a load until it is completely damaged. Loading method by providing a force that increases regularly until the structure experiences a complete failure. The bonded area in each brick shape is measured and compared with the results of the diagonal shear strength. This value is analyzed to obtain the effect on the diagonal shear strength. The percentage effect of each brick shape is compared and the results are analyzed. The results of the analysis are to obtain justification whether the area of the bad joint and head joint affects the diagonal shear strength. The novelty of this research is to obtain several brick designs that increase the strength of the diagonal shear stress. Tests show that the greater the area of the head joint, the greater the value of the diagonal shear stress.

Keywords: head joint; bed joint; shear; diagonal stress.

INTRODUCTION

Brick walls in buildings are considered non-structural and function as insulation or filler. In fact, brick walls also contribute strength to the structure, although it is small (Dawe and Seah;, 1989; Francisco J. Crisafulli, 1997; Tanganelli et al., 2018; Tomaževič, 2009). In simple houses and one-story public facility buildings, brick walls have a significant contribution, this is shown by the two functions received by brick walls, namely as insulation and transfer as well as resisting forces or functioning as a structure (Asteris et al., 2015; Farooquddin, 2000; Kałuża, 2020; Uğurlu et al., 2017).

When an earthquake occurs, the building will receive lateral forces which are resisted and transferred by beams, columns, brick walls and transmitted to the foundation. These parts will experience stylistic exposure that must be anticipated (A.W Hendry and FM Khalaf, 2001; Kałuża, 2020; Mahlil, Abdullah, 2014; Marwahyudi, 2020). The external force borne exceeds the force capacity of the structure, so the building experiences damage. The capacity of a building structure (frame building) to withstand external forces can be identified from the behavior (response) of the structure when it receives external forces.

The strength of the wall can be calculated in the laboratory. Walls exposed to earthquakes will resist diagonal shear forces. Diagonal shear strength is determined by the strength of the head joint and the bad joint supports the force. Diagonal shear strength is determined by the binding ability of the head joint and bad joint in the wall (Dautaj et al., 2019; El-dakhakhni, 2017; Lee et al., 2021; Tomaževič, 2009). The stronger the bond between the head joint and bad joint, it can be assumed that the higher the diagonal shear stress. Diagonal shear strength testing is done by making a square test object that is applied with a force in the same direction as the diagonal.

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The bed joint is the horizontal part where the mortar is attached, while the head joint is the perpendicular part where it is attached. The head joint section is easier to increase the binding area than the bed joint section. So this research focuses on the area of the bed joint.

Using bricks instead of split stones in lightweight concrete mixes is an approach that can reduce the weight of the concrete, but this can have an impact on the compressive strength of the concrete. Factors that influence the compressive strength of lightweight concrete that uses bricks as aggregate (Artawan IP et.al, 2023; Verdian R, Muin RB, 2023; Paikun P et.al, 2023). The compressive strength of the bricks used as aggregate greatly influences the final strength of the concrete. Stronger and more homogeneous bricks will produce concrete with better compressive strength. The ratio between cement, water, and aggregate (including bricks) must be adjusted precisely to achieve the desired strength and workability. Changes in these proportions can have a significant impact on the compressive strength of the concrete (Sitompul ST, Pariatmono P, 2022; Romadhon ES et.al, 2022; Widodo S et.al, 2022; Astariani NK et.al, 2023; Argoanto Y et.al, 2023).

Smaller, uniformly shaped aggregates tend to produce concrete with higher compressive strength due to more even load distribution. Lightweight concrete usually has a lower density than normal concrete. This decrease in density can reduce compressive strength, but also reduces the dead load of the structure. A good curing process is very important to develop maximum strength of concrete. Concrete that is not properly cured can have much lower compressive strength (Baggio EY et.al, 2023; Bachtiar E et.al, 2022; Priastiwi YA et.al, 2021; Bagio TH et.al, 2021).

In general, lightweight concrete with brick aggregate will have lower compressive strength than concrete with conventional split stone aggregate. Compressive strength values can vary greatly, but some studies show that lightweight concrete with brick aggregate can achieve compressive strengths of around 10-20 MPa, depending on the factors mentioned above (Gumilang PD et.al, 2021; Sutarno S et.al, 2021). However, to obtain more accurate and specific data, laboratory tests are needed that measure the compressive strength of the concrete mixture made with the proportions and types of materials that will be used in project planning (Mubarak M et.al, 2020; Marwayudi M, 2020).

RESEARCH METHODS

Materials

Diagonal shear stress testing is done by making a square test object measuring 40-120cm (Mahlil, Abdullah, 2014; Tsantilis & Triantafillou, 2018; Ullah et al., 2022), then applying pressure in the diagonal direction. When setting up the test object, do it carefully and carefully. The test object is positioned perpendicular to the diagonal direction. The test object is placed strictly upright and subjected to loading until it is completely damaged. The loading method involves applying a force that increases regularly until the structure experiences total collapse. Making two test objects in each shape. There are two samples in the normal shape, there are two samples in the Z shape, there are two samples in the hook Z shape, there are two samples in the hole Z shape and there are two samples in the hole shape. The number of test objects is two samples for each design so that there are a total of 10 test objects. Each test object measures 60 x 60 cm. It is hoped that the diagonal shear test will be able to depict real events in the field. Diagonal shear testing is intended to obtain the diagonal shear strength of each brick shape. From this analysis, new phenomena will be interesting to research. The test objects are prepared using factory-made mortar. The aim of using mortar is to obtain uniform mortar strength. After drying, the test object is colored to show damage during the compression test. Next, the test object is given water every one or two days depending on the condition of the test object. Water is given from the 2nd day to the 30th day. The test object was given a white color on the 29th day and carried out the test on the 30th day. The test was carried out in accordance with ASTM 2005 standards with the test object set up in the picture below

Figure 1. Normal bricks

Figure 2. Pit bricks

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Figure 3. Z-hole bricks

Figure 4. Z hook brick

Figure 5. Z bricks

Methods

The method of applying the load to the load cell is carried out in stages starting from 50 kg and increasing by 50 kg until the test object is damaged. Pushovers work by applying force regularly increasing until the structure experiences total collapse (Frapanti & Tarigan, 2017; Leksono, 2012; Zameeruddin & Sangle, 2021). Every time the load on the test object increases, the change number on the dial gage is recorded and all damage that occurs is analyzed. The test results are recorded and documented for analysis and calculation of diagonal shear stress. The diagonal shear stress of brick wall pairs can be calculated by laboratory shear stress using the ASTM formula. The results of observations on the load cell, dial gage and the damage that occurred were made into a table as a guide for creating a capacity curve.

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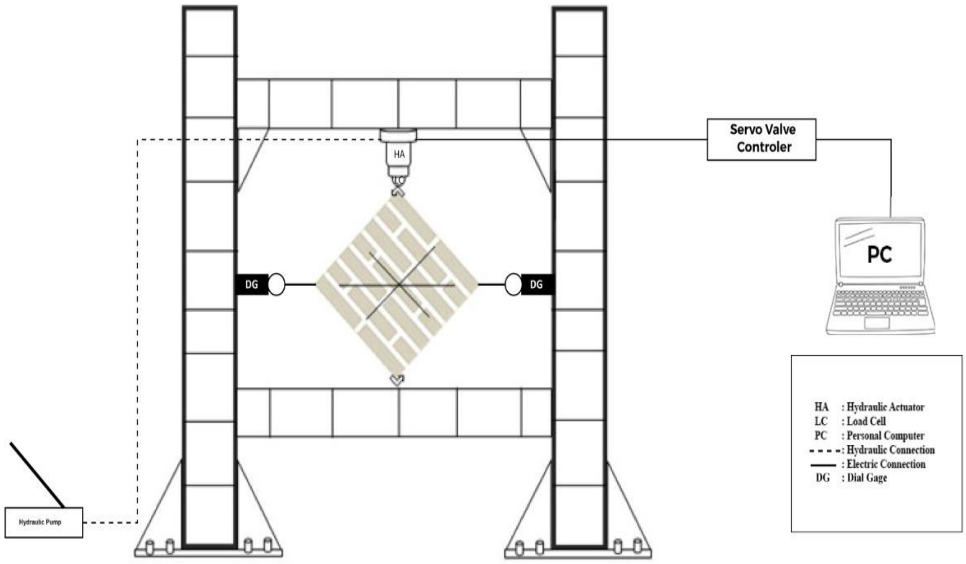

Figure 6. Set up of diagonal shear strength test of brick walls

Data Analysis

Figure 7. Set up of diagonal shear strength test of brick walls

Figure 8. Diagonal shear stress test

Shear diagonal stress is calculated from laboratory shear tests using the formula

$$Ss = \frac{0{,}707\ P}{\text{An}} \quad \text{, because} \quad An = \frac{w+h}{2} tn \quad \text{(ASTM E 519-02, 2002)}$$

Information:

Ss = diagonal shear stress (MPa)

P= maximum force resisted (N)

An = area mm2

w= width of the test object

h = height of the test object

t = thickness of the test specimen

n = aperture ratio of the test object

Table 1. Comparison of head joint areas

No	Brick	Area ratio to normal bricks (%)
1	Z	45.4545

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2	Z hook	54.5455
3	Z Hole	80.2841
4	Hole	96.3409

Table 2. Results of diagonal shear stress calculations

No	Brick	Force (N)	Voltage (MPa)
1	Normal	15500	0,166038
2	Z	19000	0,203530
3	Z hook	15000	0,160682
4	Z Hole	21000	0,224955
5	Hole	22000	0,235667

Several researchers state that the diagonal shear stress of bricks in Indonesia is 0.0709 to 0.2334 MPa (Idoarjo, 2012; Mahlil, Abdullah, 2014; Marwahyudi, 2013; Romly, 2012). Diagonal shear stress results from several designs show between 0.166038 to 0.235667 MPa.

RESULT AND DISCUSSION

Table 1 shows the head joint area ratio for various types of bricks. Table 2 shows the diagonal shear stresses in various types of bricks. Increasing the head joint area will increase the diagonal shear stress as in the picture below.

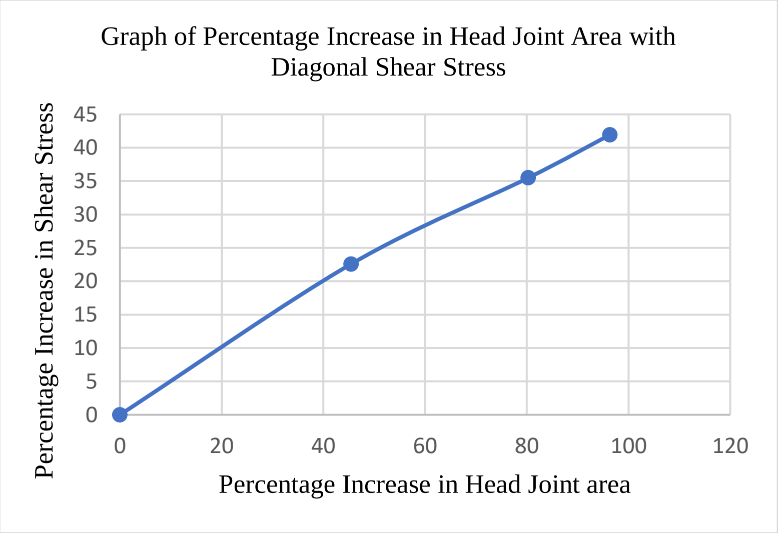

Figure 9. Graph of diagonal shear stress versus increase in Head Joint area

Figure 7 above shows that the relationship between the percentage increase in head joint area and the percentage increase in diagonal shear stress forms a linear line. This relationship is shown by an increase in area of 20% will increase about 10% of the diagonal shear stress, an increase in area of 60% will increase about 27% of the diagonal shear stress, an increase in area of 70% will increase about 33% of the diagonal shear stress

CONCLUSION

The conclusion of this research is that normal bricks reach 1550 Kgf, Z bricks reach 1900 Kgf, Z hole bricks reach 2100 Kgf, hole bricks reach 2200 Kgf. Normal bricks reach 0.16603788 MPa, Z bricks reach 0.2035303 MPa, Z hole bricks reach 0.22495455 MPa, hole bricks reach 0.23566667

MPa. Increase in the head joint area of Z bricks 45.4545%, increase in head joint area of Z hole bricks 80.2841%, increase in head joint area of hole bricks 96.3409%. From the results above, it can be concluded that the area of the head joint will increase the diagonal shear stress.

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REFERENCES

A.W Hendry and FM Khalaf. (2001). *Masonry wall construction*.

Asteris, P. G., Repapis, C. C., Tsaris, A. K., Di Trapani, F., & Cavaleri, L. (2015). Parameters affecting the fundamental period of infilled RC frame structures. *Earthquake and Structures*, *9*(5), 999–1028. https://doi.org/10.12989/eas.2015.9.5.999

ASTM E 519-02. (2002). Standard Test Method for Diagonal Tension (Shear) in Masonry Assemblages. *American Society for Testing Materials*, 5. https://doi.org/10.1520/E0519

Dautaj, A. D., Muriqi, A., Krasniqi, C., & Shatri, B. (2019). Shear resistance of masonry panel in infilled RC frames. *International Journal of Advanced Structural Engineering*, *11*(2), 165–177. https://doi.org/10.1007/s40091-019-0223-7

Dawe and Seah; (1989). *Out-of-plane resistance of concrete masonry infilled panels*.

El-dakhakhni, W. (2017). *Three-Strut Model for Concrete Masonry-Infilled Steel Frames*. *9445*(February 2003). https://doi.org/10.1061/(ASCE)0733-9445(2003)129

Farooquddin, S. (2000). *LATERAL STIFFNESS OF INFILLED FRAME WITH DOOR & WINDOW OPENINGS FOR VARYING MODULUS OF*. 7–9.

Francisco J. Crisafulli. (1997). *thesis_fulltext_masonry.pdf*. University of Canterbury.

Frapanti, S., & Tarigan, J. (2017). *Analisa Portal Yang Memperhitungkan Kekakuan dinding Batu Bata dari Berbagai Negara*.

Idoarjo, L. A. S. (2012). *S TRENGTH A ND C HARACTERISTICS O F R ED B RICK M ADE O F W ASTE S IDOARJO L APINDO M UD*. *12*(2), 121–125.

Kałuża, M. (2020). Effectiveness of shear strengthening of walls made using aac blocks - laboratory test results. *Archives of Civil Engineering*, *66*(2), 33–44. https://doi.org/10.24425/ace.2020.131794

Lee, S. J., Eom, T. S., & Yu, E. (2021). Investigation of Diagonal Strut Actions in Masonry-Infilled Reinforced Concrete Frames. *International Journal of Concrete Structures and Materials*, *15*(1). https://doi.org/10.1186/s40069-020-00440-x

Leksono, R. S. (2012). Studi Pengaruh Kekuatan Dan Kekakuan Dinding Bata Pada Bangunan Bertingkat. *Jurnal Teknik Sipil ITS*, *1*(1), 1–15.

Mahlil, Abdullah, M. A. (2014). *Alternatif perkuatan dinding untuk mencegah kehancuran brittle*. *3*(4), 77–86.

Marwahyudi. (2013). Hasil buang pabrik gula dalam dunia rekayasa teknik sipil. *Seminar Teknik Sipil UMS*, *2006*, 1–7.

Marwahyudi, M. (2020). Tegangan Geser Batu Bata Berkonstruksi Pada Dinding Rumah Rawan Gempa. *Astonjadro*, *8*(2), 80. https://doi.org/10.32832/astonjadro.v8i2.2725

Romly, M. (2012). *Uji Kuat Tekan dan Geser Dinding dengan Variasi Waktu Perendaman Bata Merah*. Universitas Negeri Jember.

Tanganelli, M., Rotunno, T., & Viti, S. (2018). On the modelling of infilled RC frames through strut models. *Cogent Engineering*, *128*(1), 1–19. https://doi.org/10.1080/23311916.2017.1371578

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Tomaževič, M. (2009). Shear resistance of masonry walls and Eurocode 6: Shear versus tensile strength of masonry. *Materials and Structures/Materiaux et Constructions*, *42*(7), 889–907. https://doi.org/10.1617/s11527-008-9430-6

Tsantilis, A. V., & Triantafillou, T. C. (2018). Innovative seismic isolation of masonry infills using cellular materials at the interface with the surrounding RC frames. *Engineering Structures*, *155*(November 2017), 279–297. https://doi.org/10.1016/j.engstruct.2017.11.025

Uğurlu, M. A., Karaşin, A., Görgün, H., & Gunaslan, E. (2017). An analytic Study on a New Semi-Rigid Infilled Shear Wall. *ASEM17*, 9.

Ullah, S., Farooq, S. H., Usman, M., Ullah, B., Hussain, M., & Hanif, A. (2022). In-Plane Seismic Strengthening of Brick Masonry Using Steel and Plastic Meshes. *Materials*, *15*(11). https://doi.org/10.3390/ma15114013

Zameeruddin, M., & Sangle, K. K. (2021). Performance-based Seismic Assessment of Reinforced Concrete Moment Resisting Frame. *Journal of King Saud University - Engineering Sciences*, *33*(3), 153–165. https://doi.org/10.1016/j.jksues.2020.04.005

Artawan, I. P., Chaerul, M., & Gusty, S. (2023). Characterization of Oil and Diesel Waste Modifiers in Lasbutag Asphalt Cold Mix (Aggregated Buton Asphalt Layer). ASTONJADRO, 12(3), 823–829. https://doi.org/10.32832/astonjadro.v12i3.13868

Verdian, R., & Muin, R. B. (2023). The effect of variation in the length of water hyacinth fiber twisted on split tensile strength high performance fiber concrete. ASTONJADRO, 12(2), 546–557. httpBaggio, E. Y., Bagio, T. H., & Tistogondo, J. (2023). Mix design programming for normal concrete using cubic equation. ASTONJADRO, 12(1), 77–85. https://doi.org/10.32832/astonjadro.v12i1.7143s://doi.org/10.32832/astonjadro.v12i2.9346

Paikun, P., Amdani, S. A., Susanto, D. A., & Saepurrahman, D. (2023). Analysis of the compressive strength of concrete from brick wall waste as a concrete mixture. ASTONJADRO, 12(1), 150–162. https://doi.org/10.32832/astonjadro.v12i1.8145

Sitompul, S. T., & Pariatmono, P. (2022). Reliability of simple space truss structure. ASTONJADRO, 11(3), 600–607. https://doi.org/10.32832/astonjadro.v11i3.7399

Romadhon, E. S., Antonius, A., & Sumirin, S. (2022). Design of Low Alkali activator Geopolymer Concrete Mixtures. ASTONJADRO, 11(3), 627–638. https://doi.org/10.32832/astonjadro.v11i3.7484

Widodo, S., Safarizki, H. A., & Marwahyudi, M. (2022). Durability of concrete based on the remaining life of the building Case study: reinforced concrete in klaten district. ASTONJADRO, 11(3), 713–720. https://doi.org/10.32832/astonjadro.v11i3.7848

Astariani, N. K., Eka Partama, I. G. N., & Dwi, I. G. A. R. C. S. (2023). Influence Substitution of Tabas Stone Waste which Coated Polyester Resin to Concrete Compressive Strength. ASTONJADRO, 12(3), 738–745. https://doi.org/10.32832/astonjadro.v12i3.9065

Argoanto, Y., Bagio, T. H., & Kusumastuti, D. (2023). Dissipating the earthquake lateral base force of structure using sliding plate and link beam base isolation. ASTONJADRO, 12(1), 42–54. https://doi.org/10.32832/astonjadro.v12i1.5289

Baggio, E. Y., Bagio, T. H., & Tistogondo, J. (2023). Mix design programming for normal concrete using cubic equation. ASTONJADRO, 12(1), 77–85. https://doi.org/10.32832/astonjadro.v12i1.7143

Bachtiar, E., Setiawan, A., & Musahir, F. (2022). HIGH STRENGTH CONCRETE USING FLY ASH A CEMENT AND FINE AGGREGATE. ASTONJADRO, 11(2), 448–457. https://doi.org/10.32832/astonjadro.v11i2.6725

Priastiwi, Y. A., Hidayat, A., Tamrin, R., & Sendrika, D. B. (2021). RESISTANCE OF MORTAR WITH PPC CEMENT AND GEOPOLYMER MORTAR WITH WHITE SOIL SUBSTITUTION IN H2SO4 IMMERSION. ASTONJADRO, 10(2), 213–224.

https://doi.org/10.32832/astonjadro.v10i2.4579

Bagio, T. H., Baggio, E. Y., Mudjanarko, S. W., & Naibaho, P. R. T. (2021). REINFORCED CONCRETE BEAM AND COLUMN PROGRAMMING BASED ON SNI:2847-2019 ON SMARTPHONE USING TEXAS INSTRUMENTS. ASTONJADRO, 10(2), 287–300. https://doi.org/10.32832/astonjadro.v10i2.5101

Gumilang, P. D., Safarisky, H. A., & Marwahyudi, M. (2021). PRESS STRONG CONCRETE ADDED SHELL OF KEONG SAWAH. ASTONJADRO, 10(1), 81–85. https://doi.org/10.32832/astonjadro.v10i1.3986

Sutarno, S., Rahmawati, D., & Masvika, H. (2021). EFFECT OF CHICKEN FEATHER WASTE ON CONCRETE MIXING ON COMPRESSIVE STRENGTH AND FLEXURAL STRENGTH. ASTONJADRO, 10(1), 162–172. https://doi.org/10.32832/astonjadro.v10i1.4330

Mubarak, M., Rulhendri, R., & Syaiful, S. (2020). PERENCANAAN PENINGKATAN PERKERASAN JALAN BETON PADA RUAS JALAN BABAKAN TENGAH KABUPATEN BOGOR. ASTONJADRO, 9(1), 1–13. https://doi.org/10.32832/astonjadro.v9i1.2694

Marwahyudi, M. (2020). STIFFNESS DINDING BATU BATA MENINGKATKAN KEKUATAN STRUKTUR. ASTONJADRO, 9(1), 30–37. https://doi.org/10.32832/astonjadro.v9i1.2840