EULER BUCKLING FAILURE MODEL AT GALVANIZED PIPE INFLUENCED BY HOLE DETERIORATION AS PITTING CORROSION MODELLED EXPERIMENTAL APPROACHMENT

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ABSTRAK

Korosi adalah fenomena alam yang tidak dapat dihindari. Hampir seluruh logam yang mengandung unsur paduan *Ferrit* akan mengalami peristiwa oksidasi sebagai penyebab korosi. Banyak konstruksi sipil yang berada di lingkungan agresif dan merupakan konstruksi-konstruksi vital yang melayani kebutuhan masyarakat banyak, semisal pelabuhan, *off shore structure, crane* dan lain sebagainya kurang memperhatikan dampak korosi yang terjadi pada konstruksi tersebut. Hal ini disebabkan salah satunya oleh formulasi analitik satu dimensi untuk menentukan beban kritis (Pcr) tidak dapat memberikan model yang optimal terhadap batang aksial tekan dengan penampang yang tidak solid (*hollow section*) seperti halnya dengan tube atau pipe dari sebuah struktur aksial tekan dengan adanya pengaruh cacat berupa lubang yang dimungkinkan akibat reaksi korosi dalam bentuk *pitting*.

Penelitian ini mengembangkan model laboratorium yang mengunakan *prototype* pipa galvanis sebanyak 16 sampel yang terdiri dari 3 sampel untuk uji pendahuluan dan sampel lainnya dengan lubang pada tengah tinggi kolom dengan rincian 3 sampel untuk lubang tunggal, selanjutnya disebut sebagai *Single Hole Pitting* (SHP) dan lainnya untuk sampel dengan jumlah lubang lebih dari satu yang terdiri dari sembilan sampel, selanjutnya disebut sebagai *Multi Hole Pitting* (MHP). Sampel MHP dan SHP memiliki korelasi sedemikian rupa terhadap parameter geometrik yang telah ditentukan sebelumnya.

Model eksperimen dalam penelitian ini memberikan nilai cukup baik dan lebih mendekati nilai beban kritis berdasarkan hasil analitik metode Euler. Meskipun demikian nilai tersebut sangat tergantung pada besaran nilai modulus elastisitas (E) yang berikan pada formulasi Euler tersebut. Hasil penelitian menunjukkan Pcr benda uji SHP lebih rendah daripada benda uji MHP *(*D24 = 15382,48 N < 6D4 = 15663,2 N). Begitu juga halnya dengan pengujian laboratorium namun efek 3-arah tekuk yang ditimbulkan oleh pipa galvanis menunjukkan perilaku yang unik terutama pada kekakuan dan orientasi tekuk yang terjadi. Penelitian ini juga membuktikan bahwa tegangan dan kosentrasi tegangan yang terjadi pada saat tekuk belum mencapai tegangan leleh.

Kata kunci: Tekuk Euler, Korosi *pitting*, modulus elastisitas.

INTRODUCTION

Corrosion is unavoidable natural phenomenon. Almost metals which compound ferrit alloys unsure get oxidation reaction that stimulate corrosion[4]. So many civil construction were located on aggressive environment such in port, *off shore structure, crane* and any else not enough consider in corrosion effects. It cause of 1-dimension analyze formulation can not give optimal buckling failure model for axial truss member by hollow section such as tube or pipe member. More over it can not give sufficient solution if the member get several deterioration i.e. holes that can be potentially caused by corrosion reaction such in pitting corrosion.

The presence of hole such in corrosion in pitting formed caused structure weakness that potential caused structure failure. The failure can be material failure or geometric failure [1]. Geometric failure caused instability of axial truss member which criteria of ultimit stress can be used as parameteric to predict the failure of pipe accurately however it is not too much conservative for severe condition[2].

Euler equation showed in equation 1 just only covered one dimentional analyze of axial structure that were caused by geometric failure. Critical load value (Pcr) can not be estimated easily in this way especially orientation and defect consideration. Hence we need an optimal experiment model to create the visualization of buckling failure then give P-δ as better out put of the experimental elastic buckling test of galvanized pipe. This research also to find the hole performance and critical load achievement correlation.

The weakness of column stability can be caused by boundary conditionof supported, slenderness, and thickness1). Instability of axial load member by Euler quantified in critical load (Pcr) that was formulated below:

$$P_{cr} = \frac{\pi^2 EI}{(Kl)^2} \qquad (1)$$

The number of slenderness is a number was found by ratio of effective length of column and its minimum radius of gyration.

$$Slenderness\ Ratio = \frac{Kl}{r} \qquad (2)$$

The other parameter need to consider is *Transition Slenderness Ratio* (Cc), which :

$$C_c = \sqrt{\frac{2\pi^2 E}{fy}} \qquad (3)$$

Number of kl/r and Cc can be quantified as parametric to determine the criteria of high or short column.

This research is an experimental case based on Miftah's experiment (2010) about Euler buckling failure of galvanized steel CHS column (galvanized pipe)[5].

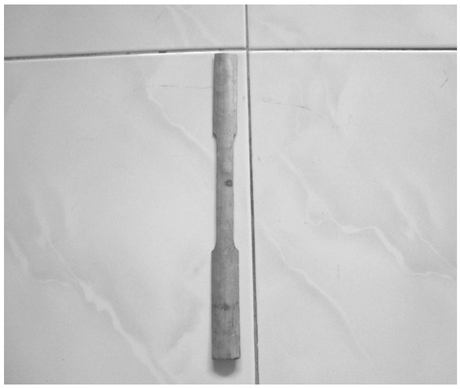
RESEARCH METHOD

The first procedure in this research is how to determine the elasticity modulus (E). The value of E in this research were determined by slope of the curve of stress-strain based on tension test. Galvanized pipe represent platform column off shore structure prototype in sample. Some sample get single hole treatment at the surface with diameter variation correspondently 24 mm; 36 mm; 48 mm and namely Single Hole Pitting, SHP. Next, the others get multi holes treatment with diameter correspondently 4 mm; 6 mm; 8 mm; and 12 mm namely Multi Holes Pitting, MHP with holes quantity correspondently 6,9,12 for 4 mm diameter; 6;3,6 for 8 mm diameter ; 2,3,4 for 12 mm diameter. Quantity and diameter of SHP and MHP have correlation in area of holes in example SHP D24 correlate into MHP 6D4, MHP 3D8 dan MHP 2D12.

Experimental Model

Pre test have done to evaluate elasticity modulus (E) of galvanized pipe STR 24 by tension test. Universal Testing Machine (UTM) Every Denison were used to observe stress and strain of the speciment by tension test.

(i)



(ii)

Figure 1. Tension Test by UTM Every Denison and The Speciment

UTM “Every-Denison” powered by electricity power which every load carried on will be showed by pointer in kilo Newton units. The number was shown must be multiplied by 0,05 as calibration factor to produce axial load force at speciment (Figure 1(ii). This equipment was also completed by extensometer to determine elongation of the speciment. The value of elongation must be multiplied by 0,001 as calibration factor to get the accuracy.

Elastic Buckling Experiment

16 Galvanized pipes 2,0 inch were prepared for the sampel with geometric specification such in outside diameter = 56,02 mm; thickness = 0,81 mm; and length = 2500 mm.

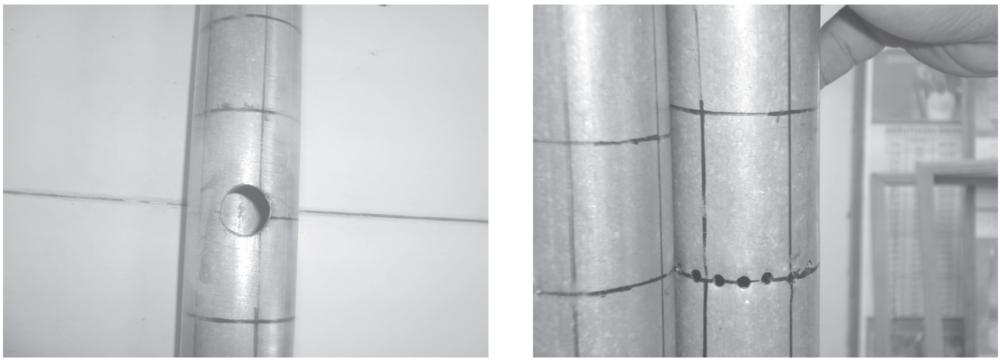


Figure 2. SHP and MHP Samples of Galvanized Pipe with Hole Treatment

Figure 2 shows the samples (SHP and MHP) were used in this project. The sample laid on pinned-pinned supported vertically. The bottom of the sample load cell 2 T and 5 T capacity were put and powered by hydraulic jack for loading transfer mechanism as shown as on experimental setting scetch below:

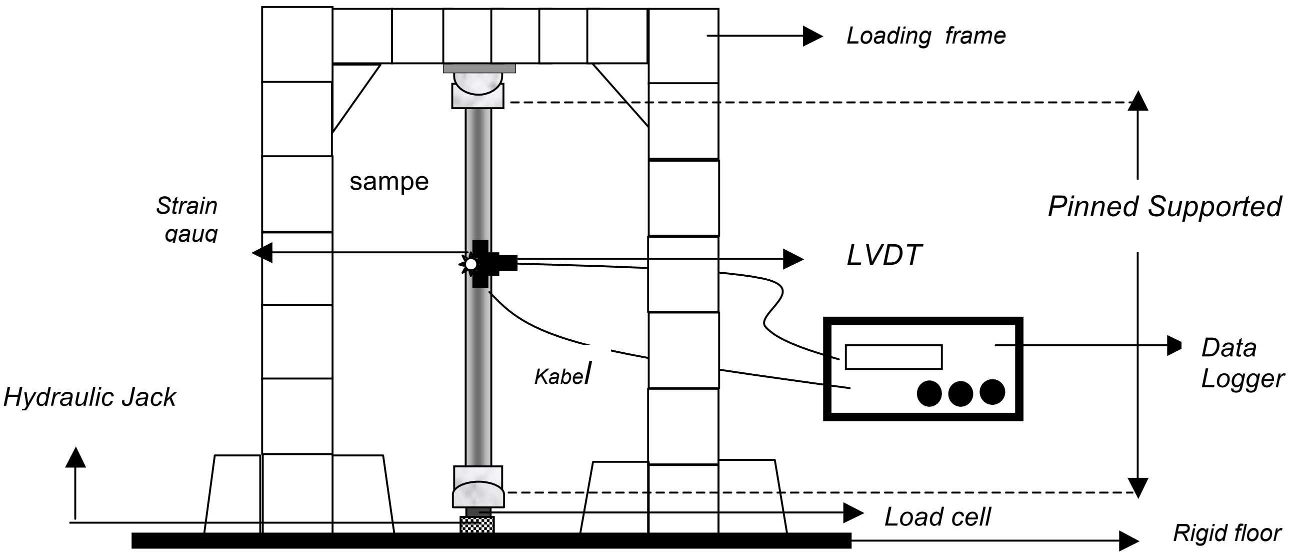


Figure 3. *Compressive Setting Test*

Linear variable differensial transformer (LVDT) were put on angle hand into length of sample at the mid span that were supported by a couple of glasses with alumunium covered to control the displacement as shown as the figure below:

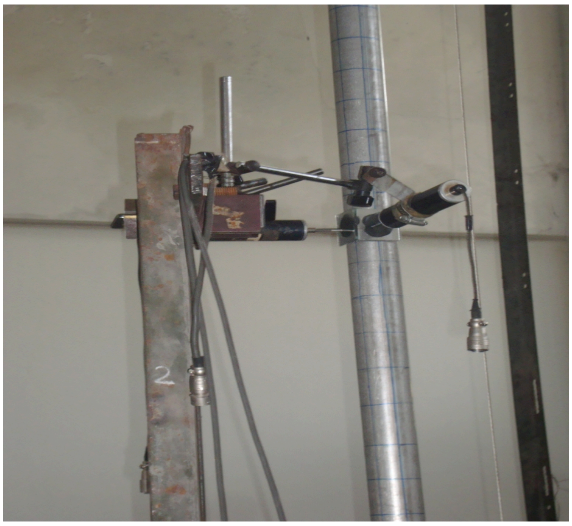


Figure 4. LVDT Setting

The function of a couple glasses to make stable position of LVDT considered cross section geometric effect as shown as Figure 4.

Straingauges were also put on middle span of sample especially at maximum tension area were supposed and severe area at surround of the holes. Rectanguler rosette strain gauges were also used in this research to investigate the stress cosentration close into the holes. Load cell, LVDT and strain gauge were connected by data logger as data recording.

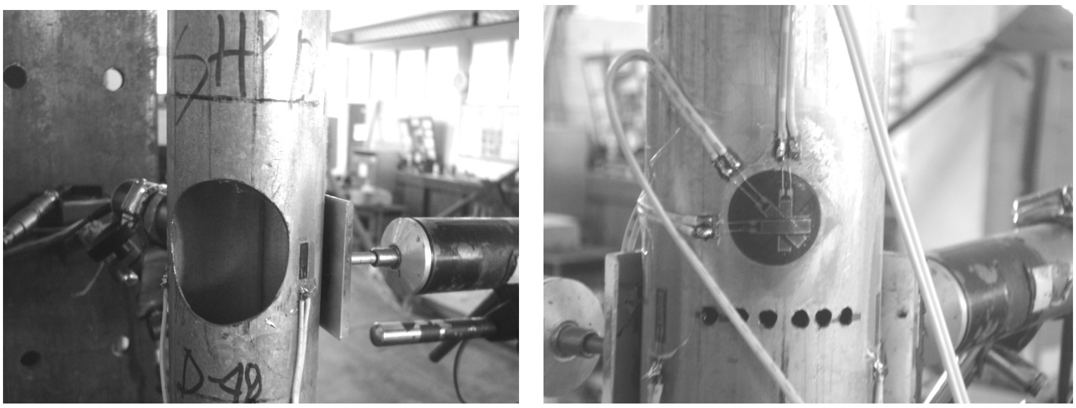
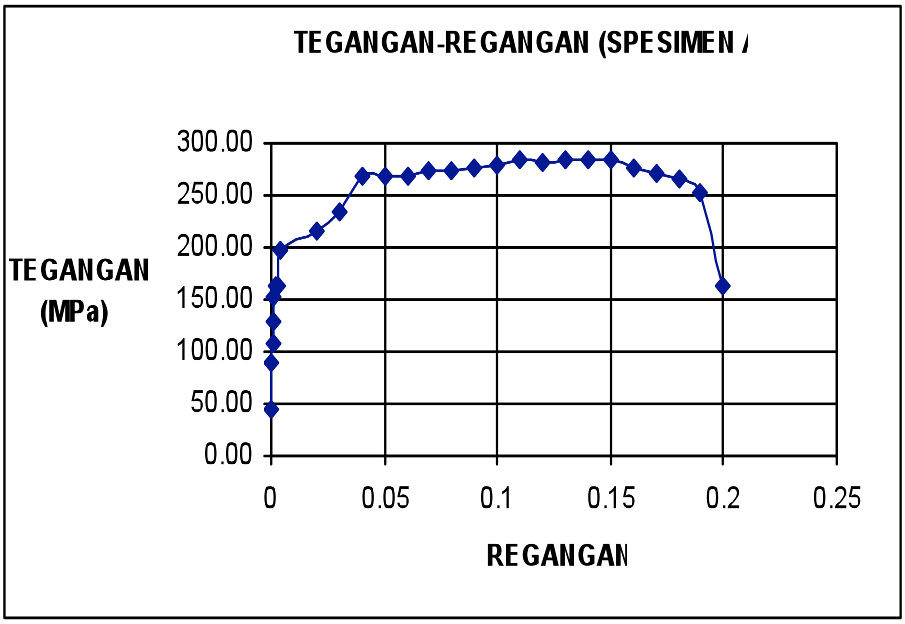


Figure 5. Strain Gauge Setting

EXPERIMENT RESULT AND DISCUSSION

Tension test result shows that stress-strain relation as shown as Figure 6 below:



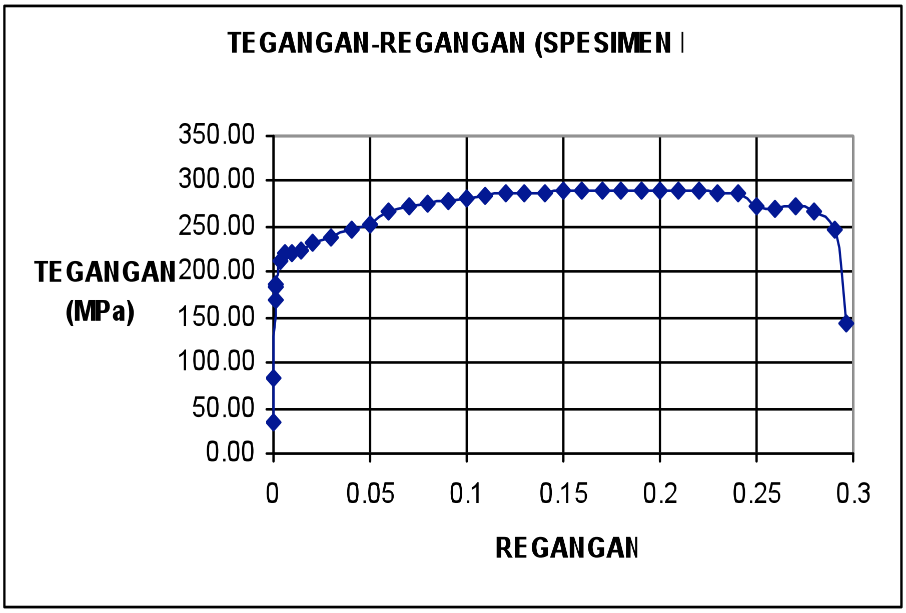


Figure 6. Stress-Strain Curve of Galvanis Pipe Tension Speciments

Figure 6 shows that the value of E correspondently for each speciment are 185185 Mpa and 249383 Mpa where the average value of E will be used 217284 Mpa. Speciment performance (plan or shell) need suit gripping tools of UTM. Hence slice and failure at the unexpected area can be avoidable[6]. There are scetch of speciment and gripping were completed by extensometer as shown as the figure 7 below:

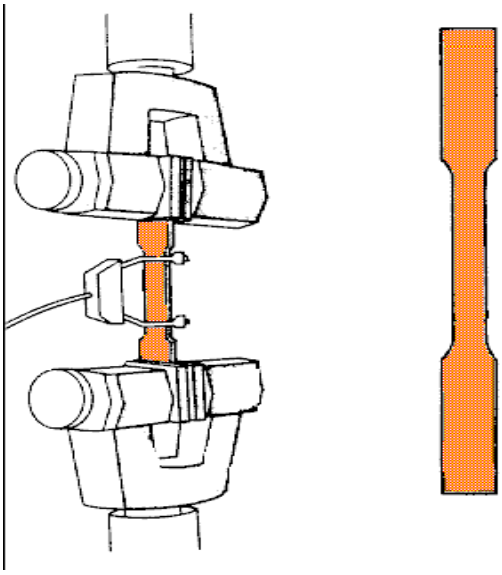


Figure 7. Speciment and Gripping

(Source: *Technical Tidbits, published by Brush Wellman Engineered Materials, Vol.3 No. 9, 2001)*

The result of three galvanized pipes compression load test without hole treatment (called control column) as shown as the figure 8 below:

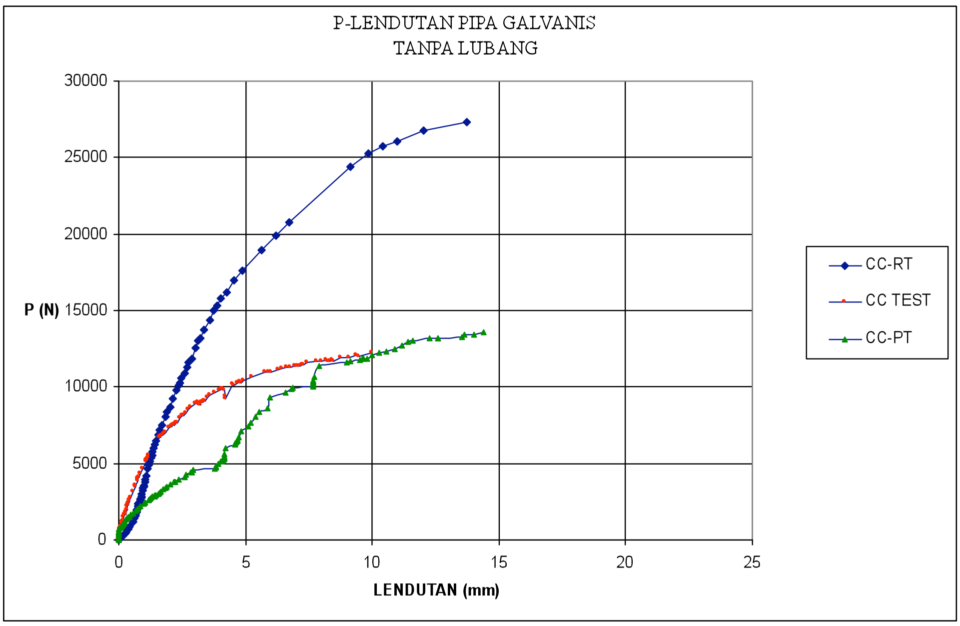
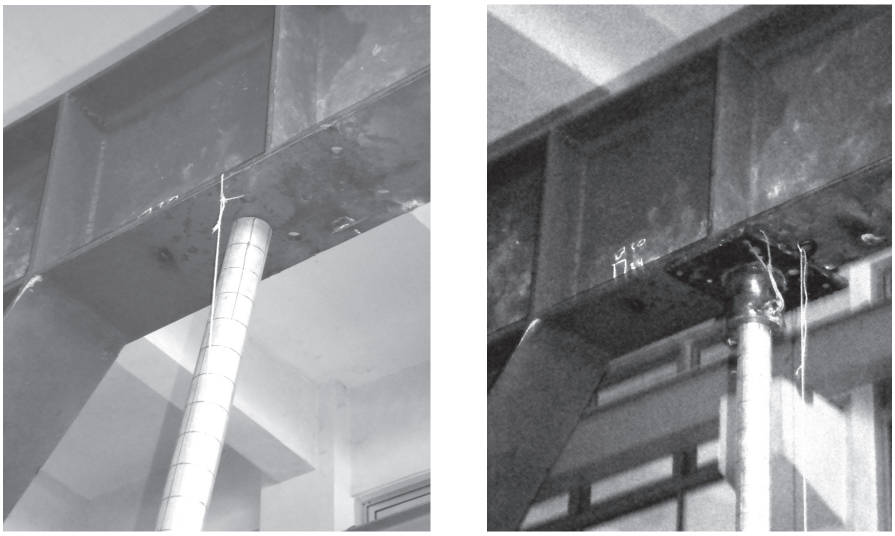


Figure 8. P-deflection laboratory test

The different value of P_{cr} showed at Figure 8, especially we have an extreem difference stiffness that were indicated by slope of he P-deflection curve. The differences were caused by:

1. Pinned – Pinned Supported Model Laboratory

The top of the pipe supported by loading frame only without any treatment to model pinned-pinned supported as shown as Figure 9 (i). This setting give translation and rotation effect of the supported was disturbed, in another word translation and rotation of the support does not give translation and rotation of pinned-pinned supported. Pinned-pined supported was designated to be model in this research (Figure 9(ii)) so be able to get perfect rotation and minimize translation effect if the member loading carried on. This type of supported made the stiffness higher than two cases of compression load test before.



(i) (ii)

Gambar 9. Pengujian tekan kolom control

2. LVDT setting up

The LVDT setting up need to be evaluated because of the fault setting up of LVDT will give miss information about the displacement. We have circular cross section sample and it can be possible slice was occurred at LVDT. Another meaning we have incorrect measurement of displacement occurred. The angle hand position of LVDT were expected to give linear vector resultant of displacement occurred. In the fact the buckle orientation is unpredicticable that showed inconsistence the read of LVDT. Using a couple of glasses is one of effort to have stable position of LVDT as shown as the figure 10 however this is not effective way in severe case, especially for the sample with in artificial holes treatment. Example we have some MHP that orientation buckle contrary moved in unexpected direction and made glasses broke.

Figure 10 LVDT Setting Up

Load –Deflection of Galvanized Pipe by Artificial Holes Treatment

All of the result test showed that buckling failure occurred as like as a truss member get the compression load carried on both of its edge. The criteria of this failure we called geometric failure that is way we always have critical load lower than yielding load of material (*instability elastic buckling failure*). This research was focused in elastic buckling failure and the P-deflection of the test showed below:

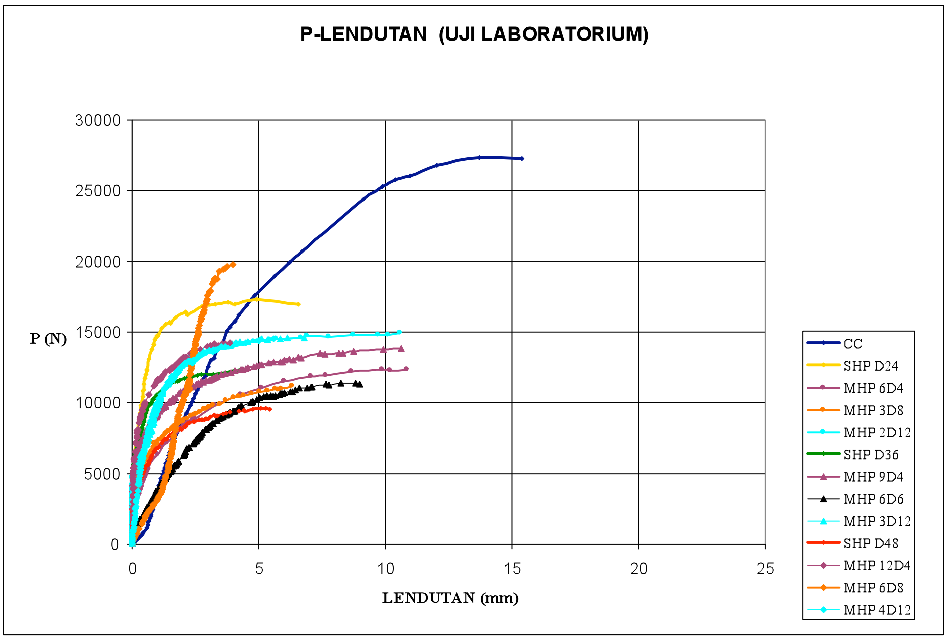


Figure 11. P-deflection laboratory test

Figure 11. showed size ncresing of diameter of artificial hole caused lower Pcr achievement. Pcr for sample MHP higher than Pcr for sample SHP. However rate of load, control LVDT and no observation at shortening member caused some uniques phenomenon in this project. The value of Pcr SHP D24 and MHP 6D8 are too high relative than the other samples and stiffness effect is one of them. This experiment has been verified by numerical analysis utilize SAP 2000[3] below:

Tabel 2. Experiment Result verified by SAP 2000

SAMPEL	UJI LABORATORIUM		SAP 2000 V. 11,00		*ERROR* (%)
	Pcr (N)	Delta (mm)	Pcr (N)	Delta (mm)	
MHP 6D4	12360,6	10,84	15663,20	22,96	26,81
MHP 3D8	11163,78	6,32	15467,79	22,98	38,55
MHP 2D12	14921,01	10,60	15670,25	22,80	5,02
MHP 9D4	13871,34	10,62	15658,78	22,90	12,96
MHP 6D6	11389,41	8,25	15452,35	22,90	35,67
MHP 3D12	14577,66	6,80	15613,67	22,92	7,11
MHP 12D4	14263,74	3,87	15655,86	22,92	9,79
MHP 6D8	19786,77	3,98	15225,99	23,03	23,05
MHP 4D12	14528,61	5,61	15611,98	22,91	7,46

Compatibility of model by utilize SAP 2000 for axial truss member with deterioration such artificial hole showed that *quadrilateral shell* element have not yet give satisfication result but generally this value is acceptable because we have correct trends that show increasing of size of artificial holes so we have lower Pcr. In another hand decresing of quantity of hole we have highest Pcr.

Stress

Figure 11. showed that increasing of size of artificial hole so we have the lower stress. All stress occurred in tension area lower than yielding stress off material. Hence this situation indicated that buckle occurred at load smaller than yield load.

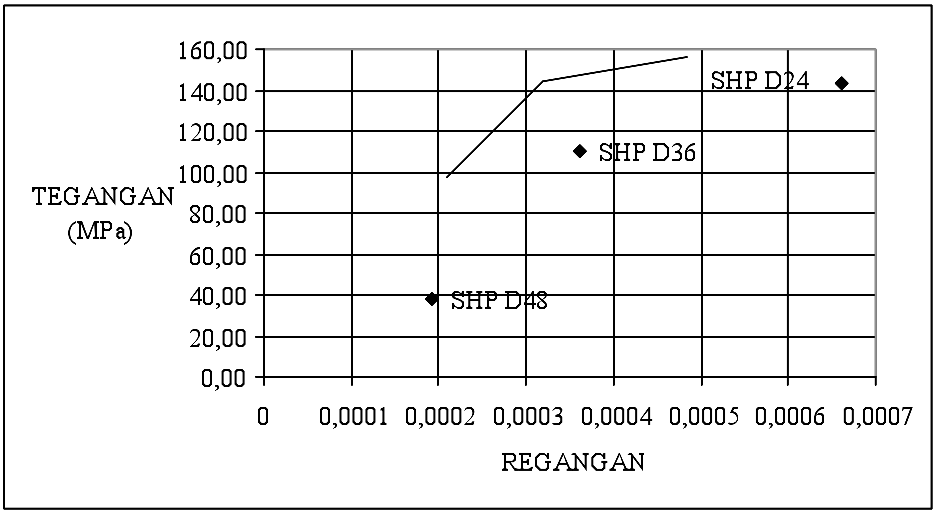


Figure 12. Stress of SHP sample

CONCLUSSION

1. Type of gripping at Universal Test Machine give significance influence on strain measurement of tension test case.
2. Instability of measurement caused data misinterpreted of stress-strain relation than caused invalid elasticity modulus.
3. Increasing of size of artificial holes caused lower Pcr achievement in prosentage correspondently 2,24%; 5,70% dan 19,62%.
4. Sample by many holes but in little size give relative higher Pcr than sample with less holes in big size artificial hole.
5. Stress when buckle occured lower than yielding stress.
6. The value of modulus elasticity is the main factor to determine compatbility numerical and laboratory model.
7. Severe uniques in this research caused by supported mode, LVDT interpreted, straingauge position.

SUGGESTION

1. The other research more intens on galvanized pipe properties material to find valid modulus of elasticity.
2. Stress cosentration of pitting corrosion need to be observed to give verification of this research.
3. Laboratory test should based on standard, such as ASTM, SNI and the others and get attention on to rate of load, gripping type, LVDT and straingauges position.
4. LVDT setting up better to find accurat deflection read.
5. The orientation of buckle need to be controlled to get stable measurement.

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