Revision Report

Paper ID : **62**
Paper Title : Analysis of The Sand Grains Influence on Damping Ratio Using Shear Test
Review Number : **1**

Revision report (for the papers "Minor revision" or "Major revision")

No.	Location		Reviewer's comment/request/question	Your resulting revision
	Page no.	No. of line/ figure/table		
1.			Writing format could be improved	The format has been improved according to the guidelines.

Revision Report

Paper ID : **62**
Paper Title : Analysis of The Sand Grains Influence on Damping Ratio Using Shear Test
Review Number : **2**

Revision report (for the papers "Minor revision" or "Major revision")

No.	Location		Reviewer's comment/request/question	Your resulting revision
	Page no.	No. of line/ figure/table		
1.			Citation must be in bracketed number style e.g. [1], [2], [3], etc.	Citations are bracketed.
2.			Reference [1]-[11] are not cited in the manuscript	The references are cited
3.	1		-Missing parts? no Literature review at all	Literature review has been placed in Chapter 1
4.	4		No symbol explanation for the equation?	Symbol explanation has been added.

Revision Report

Paper ID : **62**
Paper Title : Analysis of The Sand Grains Influence on Damping Ratio Using Shear Test
Review Number : **3**

Revision report (for the papers "Minor revision" or "Major revision")

No.	Location		Reviewer's comment/request/question	Your resulting revision
	Page no.	No. of line/ figure/table		
1.	1	Chapter 1 line 3	There are some typos for example: "said structure", must be "substruc-ture".	Typos have been fixed.
2.	6	Line 1	Please mention which figure shown the damping experiment with the con-tainer without sand conducted five times.	The figure has been mentioned.
3.	7	Line 5	What is the relation between Figure 6 and Figure 3? Please describe and state the reason in your manuscript the damping ratio in Figure 6 categorized as critically damped or overdamped?	The damping ratio in Figure 6 has been categorized.

Analysis of The Sand Grains Influence on Damping Ratio Using Shear Test

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Abstract. Earthquake resistant structural building design is a necessity nowadays. Therefore, the development of earthquake damping device is indispensable. This research focuses on the usage of sand as an additional damping material on a silencer attached to the building structure. The selection of sand as additional damper is based on the grains shape which could provide additional internal friction between each grain to cause damping. This research is conducted on various types of grains size retained on the sieve analysis with uniform composition within the container and thin plate as oscillating contact area in the sand. The thin plate is connected to perfectly fixed acrylic free end tube. The sensor used is a device to gather oscillation data to be processed for the value of damping ratio to be known. The experimental result shows the disproportionate damping ratio (ξ) increment to the increase of contact area (A) and the sand shear angle.

Keywords: Sand, damping, stiffness

1 Introduction

In seismic resistant structure design, there is a particular technique to transfer earthquake force from the main structure to specially designed earthquake damping device to absorb the force from the substructure [1]. To reduce the damage occurred to the structure even further, the earthquake damping device could be set right to the main structure. Passive structure control system by mass and stiffness modifying or by the addition of damping material to control the lateral dynamic structure control, including earthquake force [1–3].The ability of the earthquake damping device to reduce the seismic force is heavily entwined to the making material [3]. In this research, an experiment against sand for additional earthquake damping device material was conducted due to the sand's ability to dampen the seismic force.

The purpose of this study is to determine the effect of sand materials due to friction between the uniform sand grains and to determine damping ratio (ξ) of the sand constituent itself. This study rather focused on establishing the outcome on the usage of sand grain size to damping that occurred between sand grains and distinguish the affiliation between piston's contact area to damping ratio.

From the analysis carried out, it is expected that the uniform shape of the sand grains will cause friction between the sand itself, causing damping [4]. The shear angle in the sand that of 45° will produce a large coefficient of friction ($\mu = \tan \alpha = 1$). A large coefficient of friction will contribute greatly to damping [5, 6]. Several analyses to various scope of problem will take place, in which the sand grains used are the ones with uniform grain size composition that retained on the sieve no. 4, 10, 20, 40, and 60. The was only carried out to determine the damping ratio of the sand grain material. The data obtained on this study are experimental data.

2 Research Methods

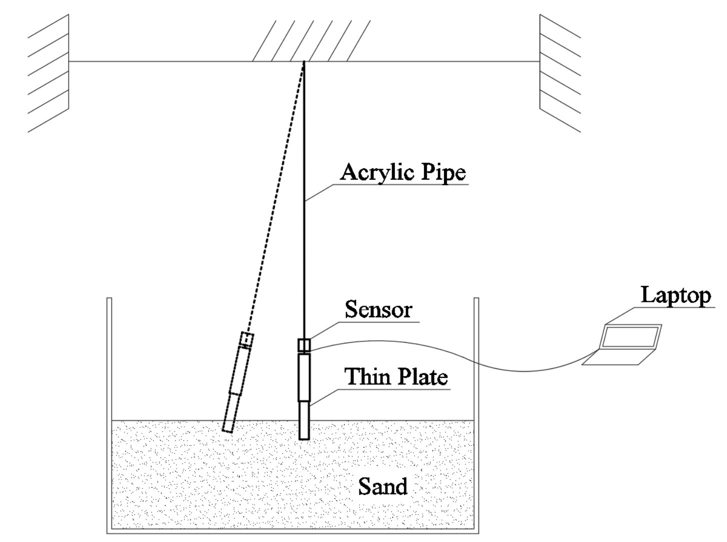

Fig. 1. Damping experiment schematics

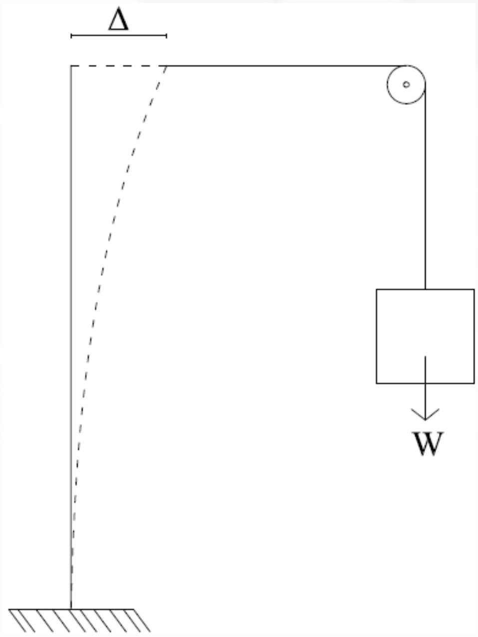

Fig. 2. Rod used to determine rod stiffness

The value of deviation and vibration time produced on **Fig. 3** will be obtained upon oscillating the rod as seen in **Fig. 2** [7].

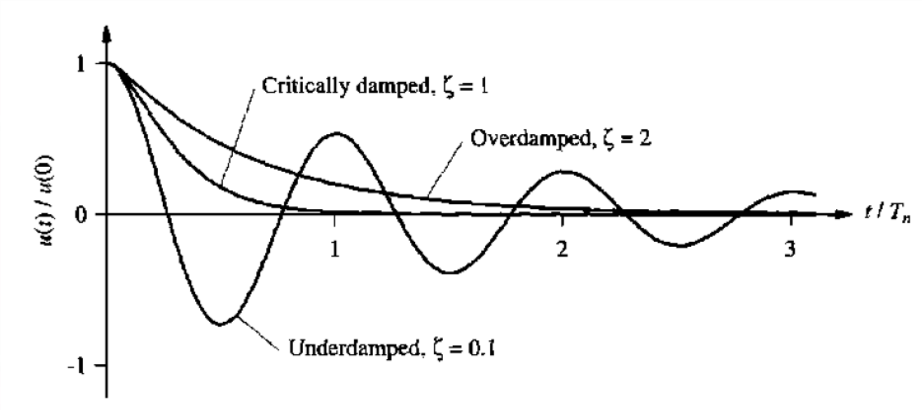

Fig. 3. Critical and supercritical chart [8]

The equation of the chart is as follows:

- Critical condition [8, 9]:

$$U = e^{-\omega t} \{U_0 + (\mathring{U}_0 + \omega U_0)\, t\} \tag{1}$$

$$\xi = 1 \rightarrow C = C_{cr} \tag{2}$$

$$C_{cr} = 2M\omega = 2\sqrt{KM} \tag{3}$$

- Supercritical condition:

$$U = A \times e^{P_1 \times t} + B \times e^{P_2 \times t} \tag{4}$$

$$A = \frac{\mathring{U} - U_0 P_2}{P_1 P_2} \tag{5}$$

$$B = \frac{U_0 P_1 - \mathring{U}}{P_1 P_2} \tag{6}$$

$$P_1 = -\xi\omega + \omega_D \tag{7}$$

$$P_2 = -\xi\omega - \omega_D \tag{8}$$

$$\omega_D = \omega\sqrt{\xi^2 - 1} \tag{9}$$

where:
$\dot{U}$ = velocity (m/s)
U = displacement (m)
M = mass (kg)
C = damping (N.s/m)
k = stiffness (N/m)
ξ = damping ratio
ω_n = natural frequency of undamped vibration (rad/s)
ω_d = natural frequency of damped vibration (rad/s)
t = time variable (s)
U_0 = initial displacement (m)
$\dot{U}_0$ = initial velocity (m/s)

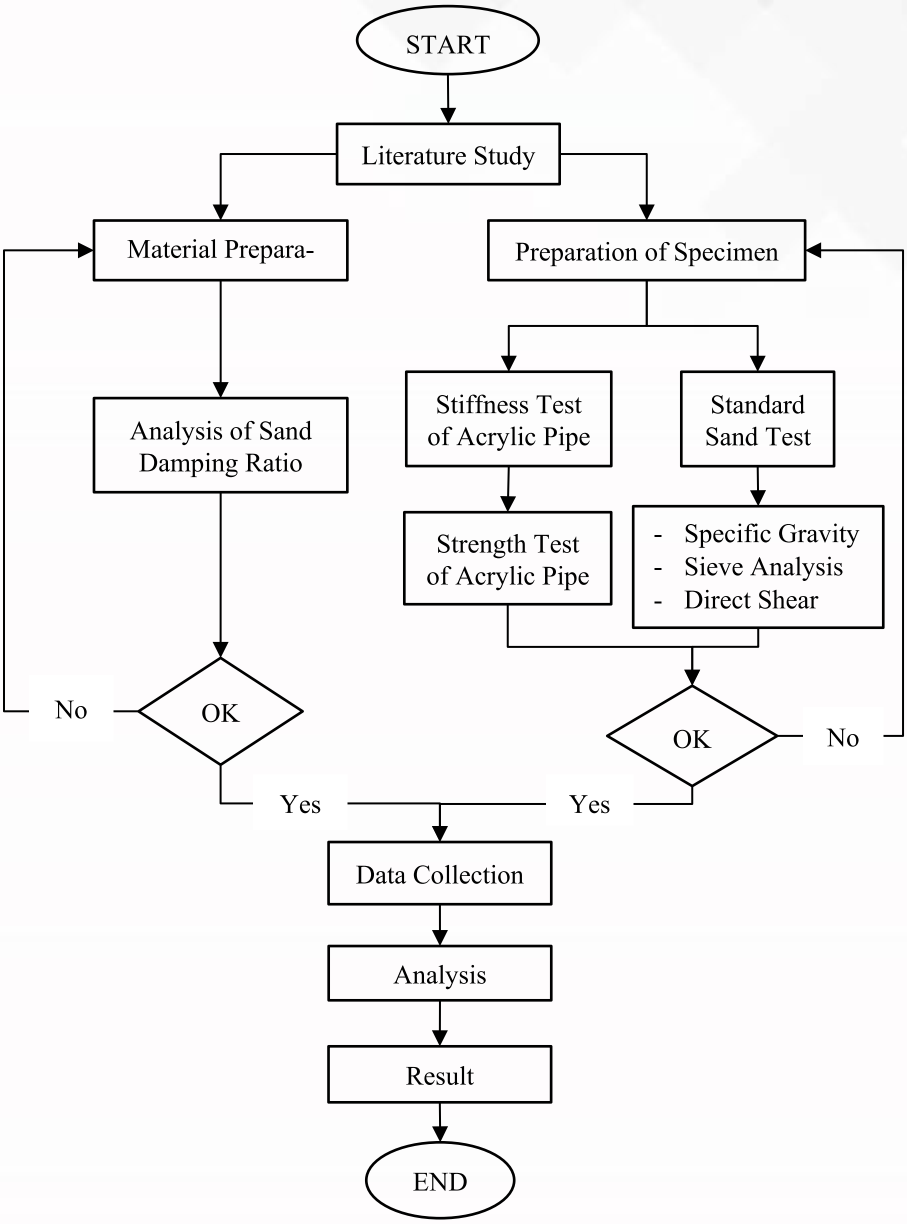

Fig. 4. Research flow chart

The variable used for the sand grains diameter used for the damping experiment of (0.850 mm, 0.425 mm, 0.250 mm), the contact area of (4.5 cm^2, 6 cm^2, 7.2 cm^2, 8.4 cm^2, 9.35 cm^2), done five times.

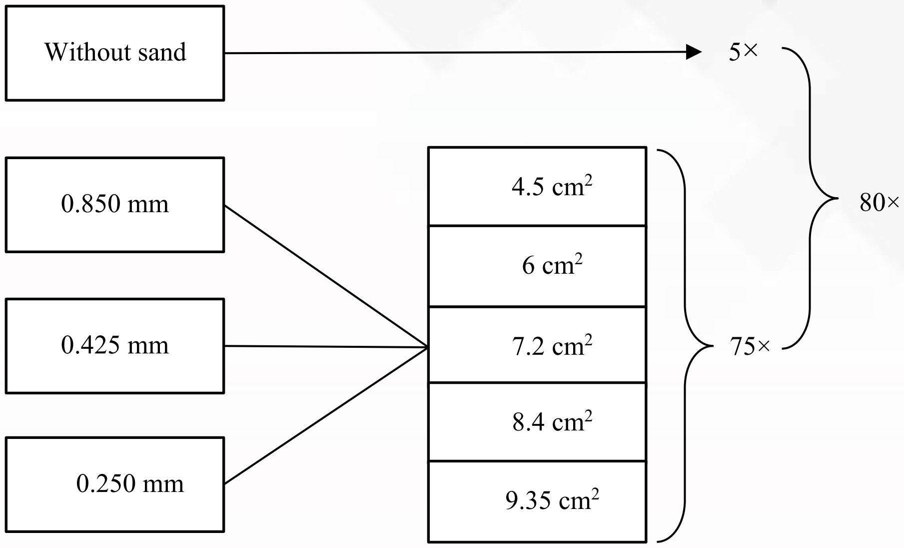

Fig. 5. Variables in damping experiments

As identified in **Fig. 5**, the damping experiment with container without sand conducted five times and for the sand grains diameter 0.850 mm, 0.425 mm, 0.250 mm done five times with each contact area of 4.5 cm^2, 6 cm^2, 7.2 cm^2, 8.4 cm^2, 9.35 cm^2. The whole damping experiments totaled to 80 times.

The damping ratio is obtained after carrying out damping experiments in the laboratory as seen in the formula below [8, 9].

$$\xi = \frac{1}{2\pi j}\ ln\left(\frac{u_i}{u_{i+j}}\right) \quad (10)$$

3 Results

The relation between the damping and contact area that is directly related to the sand grains can be seen in **Fig. 6**.

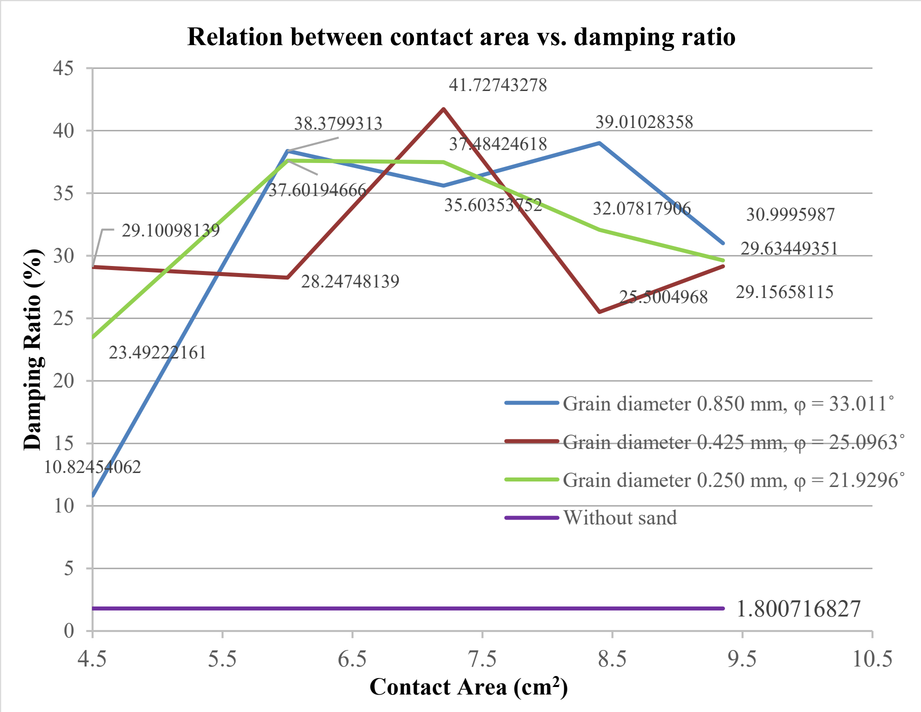

Fig. 6. Relation between contact area vs. damping ratio

As seen in **Fig. 6**, the increment of damping ratio (ξ) is not proportional to the increment of contact area (A) and the sand grains diameter. The maximum damping ratio (ξ) value to each sand grains diameter did not happened on the same contact area (A). According to the provided analysis, the conclusion of contact area and sand grains diameter do not affect sand damping ratio (ξ) could be reach. It has been determined that this research's damping ratio is classified as subcritical (under damped) on the grounds that obtained damping ratio fall behind 100%.

4 Conclusion

Based on the test results, several conclusions can be drawn, namely the increase in the damping ratio (ξ) is not proportional to the increase of contact area (A) and sand grains diameters. The increase in the damping ratio (ξ) is not proportional to the increase of contact area (A) and sand shear angle. Each of the sand grains diameter has a maximum damping ratio (ξ) in a certain contact area (A). The value of damping ratio is influenced by the value of the coefficient of friction (μ) between the thin plate with sand. The damping ratio (ξ) in sand with a diameter of 0.850 mm ranges from 10.8245% to 39.0103%. The damping ratio (ξ) in sand with a diameter of 0.425 mm ranges from 25.5005% to 41.7274%. The damping ratio (ξ) in sand with a diameter of 0.250 mm ranges from 23.4922% to 37.6019%.

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