Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

Measurement of Dynamic Friction Coefficient on the Irregular Free Surface

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1. Introduction

A spent fuel storage cask must be estimated for a structural integrity when an earthquake occurs because it freely stands on ground surface without a restriction condition[1]. Usually the integrity estimation for a seismic load is performed by a FEM analysis, the friction coefficient for a standing surface is an important parameter in seismic analysis when a sliding happens. When a storage cask is placed on an irregular ground surface, measuring a friction coefficient of an irregular surface is very difficult because the friction coefficient is affected by the surface condition. In this research, dynamic friction coefficients on the irregular surfaces between a concrete cylinder block and a flat concrete slab are measured with two methods by one direction actuator as shown in Fig.1.

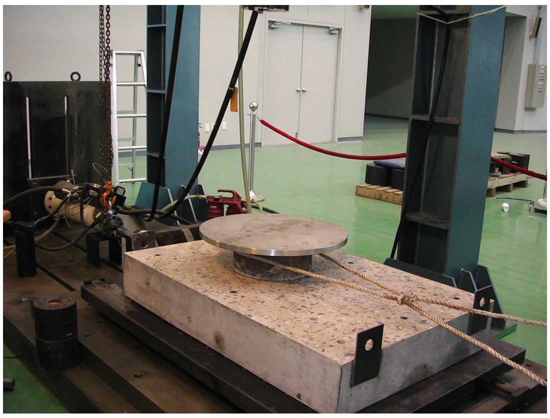


Figure 1. Coulomb's friction tests between a concrete cylinder block and a flat concrete slab

2. Friction Tests and Results

There are several calculation methods for obtaining a friction coefficient, such as Coulomb's method[2], the slip ratio method[3], sinusoidal wave method[4]. In this study, the Coulomb's simple method and sinusoidal exciting method are used in measuring the dynamic friction coefficients.

2.1 Friction coefficients

The friction coefficient by Coulomb's method is calculated by the equation (1).

$$F = \mu N \quad (1)$$

Here, F : Friction force, N : Normal force.

The friction coefficient by the sinusoidal wave method is calculated by the rate of the accelerations that are measured in the contacted two parts[4]. When the accelerations of two objects are different, the friction coefficient can be calculated by the following equation [4].

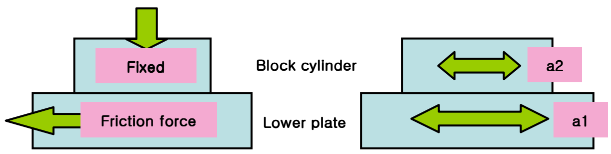
$$\mu = \frac{a_2}{a_1} \quad (2)$$

Here, a_1 : acceleration of input part, a_2 :acceleration of output part.

2.2 Friction tests

A Coulomb's friction test as shown in Fig.2(a) is performed by pulling the lower plate. The friction force(F) is measured by the load cell of the lower plate. The normal force(N) is equal to the weight of cylinder block. Several Coulomb's friction tests were performed by changing the cylinder block.

The sinusoidal friction tests as shown in Fig.2(b) are performed by giving some sine waves (1~2.5Hz) to the lower plate. The acceleration sensors attached at the lower plate and the upper body measure the accelerations of two objects. At the test for a 1Hz sine wave, the body did not move, the accelerations of the two parts are same. The upper body began to move at 2.5Hz sine wave. The accelerations of two parts are same at early, but show a difference after 2 seconds. The effects on the friction coefficient by the exciting frequency and the weight of the body are searched.



(a)Coulomb's friction test (b)Sinusoidal friction test
Figure 2. Friction tests on free surface

2.3 Results and discussions

The friction coefficient was calculated by equation (1). Fig.3 shows the results of the Coulomb's friction tests for the case 2. The friction coefficients show a large variation. Through the averaging the data, the friction coefficient was calculated by 0.544. Other results are represented in Table.1.

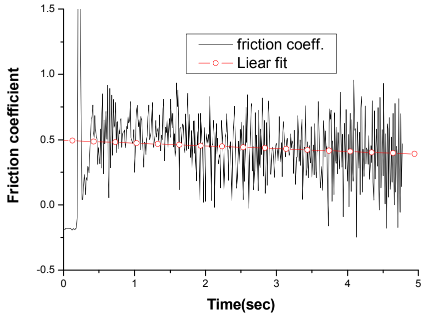


Figure 3. Coulomb's friction test for case 2.

Figs.4&5 show the results of the sinusoidal friction tests. Fig.4 shows the time history of the acceleration during 20 seconds. Since the acceleration values of a_1 and a_2 of the two parts are same, the friction coefficient can not be calculated by equation (1).

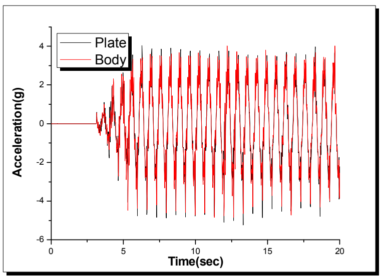
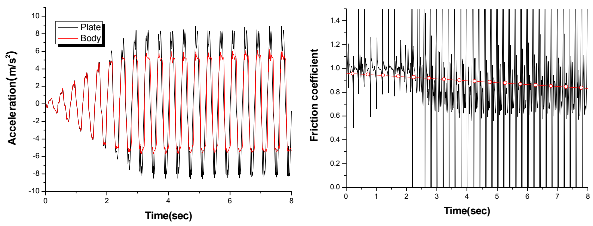


Figure 4. Friction test at sine wave (1Hz)

Fig.5(a) shows the acceleration time history responses of the upper body and the lower plate when a relative movement was occurred. The acceleration is increased until 2 seconds, but the acceleration difference is not observed. The acceleration begins to show a difference after 2 seconds, and the acceleration difference converges to a constant after 3 seconds.

Fig.5(b) represents the time history of the non-averaged acceleration ratios of the two parts. The friction coefficient by equation (1) is calculated by 0.703. Other results are represented in Table 1.



(a)Acceleration (b) Friction coefficient
Figure 5. Friction test at sine wave (2.5Hz)

The friction coefficients are a large difference between the Coulomb's friction and sinusoidal wave friction values as shown in Table.1. It is necessary to precisely study about the sinusoidal friction equation (2). To get the correct friction coefficients by a sinusoidal method, a lots of test data are required. And the equation (2) should be applied when the acceleration directions of the two parts are coincident. However the shape of the upper body in this test is a circular type, a spinning motion of the body can be occurred during a relative movement on the lower plate. In this case, the acceleration directions of the cylinder block and the lower plate can be changed.

Table.1 The friction coefficients

Model (weight, kg)	Coulomb's friction	Sinusoidal Friction (2.5Hz)
1(65)	0.324	0.703
2(63.5)	0.454	0.858
3(62.6)	0.563	0.958
4(88.65)	0.544	0.682
5(123.15)	0.443	0.587

3. Conclusion

The Coulomb's frictions are calculated by the friction force(F) and the normal force(N). The friction force is measured by the load cell and the normal force is the weight of a cylinder block. The friction coefficient was calculated by using the measured accelerations of the contacted two parts by sinusoidal wave method. When the measured accelerations are different, the friction coefficient converges to a certain value less than 1. The friction coefficients are much difference depending on the test methods.

Therefore, a further study is necessary to get more accurate friction coefficient.

Acknowledgement

This study was supported by the Korean Ministry of Commerce, Industy & Energy through its Electric Power Industy R&D Program

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