Simple Examples for Dynamics of a Single Flexible Block

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1. Introduction

Graphite fuel blocks and reflector blocks are major components of a prismatic type HTGR. An earthquake loading on the stacked blocks causes rocking responses and solid impacts between them, and may lead to structural integrity problems. The dynamic analysis of block structures has a long history.

A basic understanding of the rocking response of a rigid block resting on a rigid floor had not been well established until when G.W. Housner first presented it in 1963 [1]. In 1975, T.H. Lee presented a methodology for analyzing the nonlinear response of a column of stacked prismatic fuel blocks [2]. In 1979 T. Ikushima and T. Nakazawa presented their work results on a seismic analysis of a column of stacked prismatic fuel blocks [3]. A stochastic analysis methodology for a rocking block was introduced by Pol D. Spanos and Aik-Sion Koh [4]. S. J. Hogan considered the dynamics of a slender rigid block mounted on a vibrating rigid table with side walls [5].

Although, several novel methodologies and studies for a single rigid block and stacked rigid blocks have been presented, less attention has been paid to the dynamics of flexible blocks. This paper presents the dynamics and responses of a single flexible block on a vibrating floor, and compares them to the classical ones with a rigid assumption. The numerical model for the single flexible block is from Ref. [6].

2. Dynamic Models of Blocks

Classical single rigid block model

G.W. Housner considered a linearized equation of motion of a single rigid block on a rigid floor and showed that the rocking period is a function of the angular displacement of the block, see Figure 1.

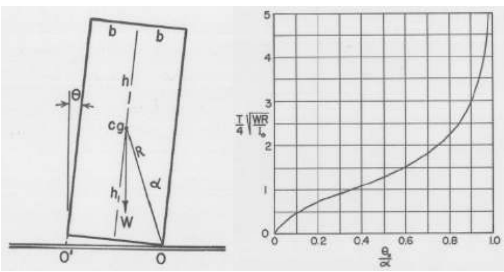


Figure 1. Housner's block model and the period of rocking motion as a function of initial angular displacement

Single flexible block model

In the numerical model considered, a flexible block is assumed as two rigid sub-blocks connected by a pin joint at the geometric center *C* and two angular springs between them, as shown in Figure 2. This flexible block model will oscillate about the centers of rotation *O* and *O*' when it is rocking, and the upper sub-block can rotate about the block center *C*. It is assumed that the coefficient of friction between the floor and the lower sub-block is sufficiently large so there will be no sliding for all motions.

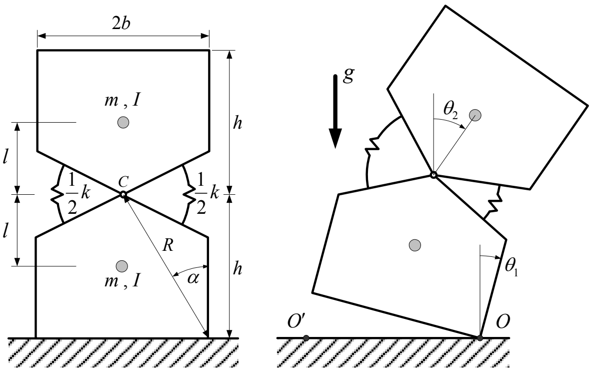


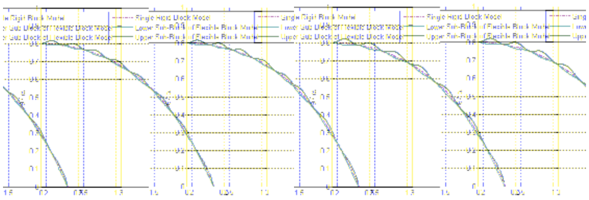
Figure 5. Geometry and degrees of freedom of the proposed flexible block model

3. Dynamics of a Single Flexible Block: Simple examples

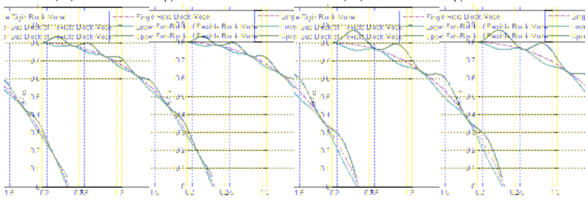
Dynamic characteristics of the proposed flexible block model are compared with those of Housner's single rigid block model. Block movements starting at an initial angular displacement, $\theta/\alpha = 0.8$, are compared with each other with different rigidity values, $k_{\text{bend}} / k_{\text{grav}} = 80, 60, 40, 20$, as shown in Figure 3. Before the first impact on the floor, the block motions are quite similar to each other in a macroscopic view, although the ripple amplitudes increase with decrease of the rigidity. An interesting point is that the time to the first impact of the flexible models is no later than that of the rigid block model in all cases.

Decaying rocking responses of the block models with different initial angular displacements, $\theta/\alpha = 0.8, 0.6, 0.4, 0.2$, are compared when the block rigidity is 100 and the kinetic energy reduction ratio is 0.9, as shown in Figure 4. As the maximum tilting angle decays after an impact on the floor, the rocking period shortens. But the rocking period shortening is noticeable in the flexible block model cases. The ripple motion of the upper sub-block of the flexible block models becomes more dominant with the amplitude of rocking motion decaying.

Responses of the block models on a vibrating floor with different kinetic energy reductions are compared. Figure 5 shows that the responses of a flexible block model are quite different from those of a single rigid block model, while in the above observations they show similar trends. All the block models on a vibrating floor fall down when the vibration acceleration of the floor is 0.4g and $r > 0.5$, the first three cases in Figure 8. But fall down times and directions of the flexible block models are different from those of the rigid block models. In the last case $r = 0.5$, only the flexible block model falls down.

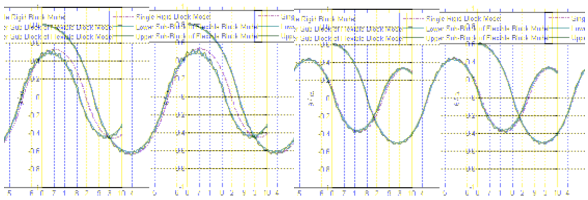


(a) $k_{bend} / k_{grav} = 80$ (b) $k_{bend} / k_{grav} = 60$

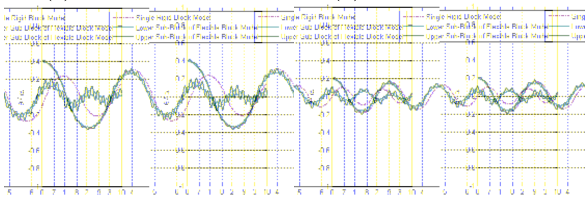


(c) $k_{bend} / k_{grav} = 40$ (d) $k_{bend} / k_{grav} = 20$

Figure 6. Block motions with initial angular displacements and the effect of the rigidity.

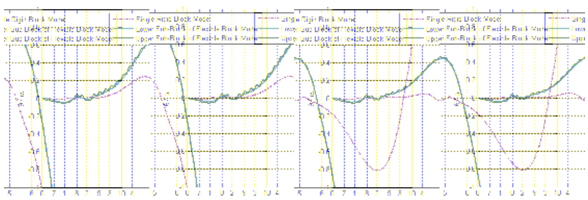


(a) Initial $\theta/\alpha = 0.8$ (b) Initial $\theta/\alpha = 0.6$

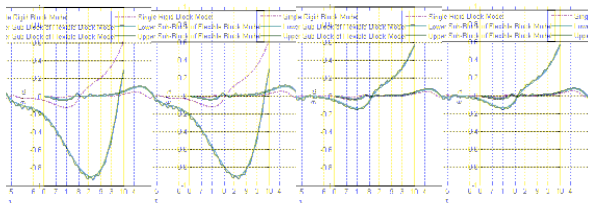


(c) Initial $\theta/\alpha = 0.4$ (d) Initial $\theta/\alpha = 0.2$

Figure 7. Free rocking motion of the blocks with different initial displacements when $k_{bend} / k_{grav} = 100$, $r = 0.9$.



(a) $r = 1.0$ (b) $r = 0.9$



(c) $r = 0.7$ (d) $r = 0.5$

Figure 8. Responses of blocks on a moving floor with different reductions of the kinetic energy, r, when $k_{bend} / k_{grav} = 100$.

3. Conclusion

The dynamics of the single flexible block model were compared with those of the single rigid block model. It was shown that the falling down of a flexible block occurs earlier than the rigid block cases, although they show similar dynamics. An extended study on the single flexible block model will be presented later.

ACKNOWLEDGMENTS

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