TRANSFORMED GYRO-LUMPED PARAMETER MODEL AND ITS APPLICATION TO MULTI-STORY BUILDINGS

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1. INTRODUCTION

In general, the impedance functions (IFs) of the soil-foundation system show frequency dependent characteristics and thus frequency domain analysis is compulsory to incorporate them. However, time history analysis is mandatory to integrate the inelastic behavior of materials and structural members which strongly depends on the stress path being integrated stepwise[1]. Although varieties of methods are available to consider the frequency dependent IFs in a time history analysis, they are either very complex for practical use having many numbers of elements and degrees of freedom or they do not represent the frequency dependent IFs with sufficient accuracy.

Recently, Saitoh[1] proposed a simple lumped parameter model with gyro-element (GLPMs) which is considered to be a sophisticated model for representing frequency dependent IFs[2]. However, the implementation of the GLPMs model in the conventional software in the practical application remains left.

In this study, a transformation methodology of GLPMs has been proposed and verified by using it in a single degree of freedom (SDOF) structural system supported by pile foundation taken from a literature[2] in the frame work of Open System for Earthquake Engineering Simulation (OpenSees). Transformed GLPMs are then applied to a three dimensional multi-degree-of-freedom system in OpenSees. The effect of frequency dependent IFs on the structural response is studied in terms of the time-history responses and inter-story drift. The input motions are magnified to make the structural behavior in inelastic region.

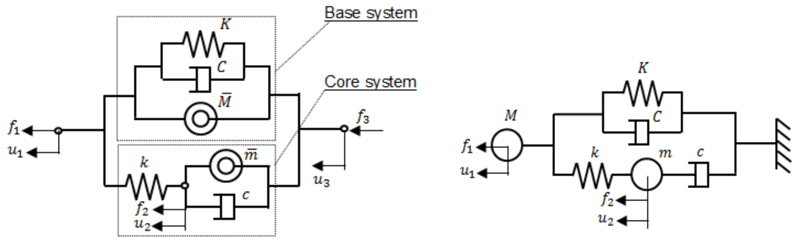

Fig. 1 The original type II GLPMs model [1] (a); and the transformed GLPMs (b)

2. GLPMS AND ITS TRANSFORMATION

The GLPMs consist of conventional springs and dashpots and newly proposed gyro-elements (Fig 1(a)). Further details of GLPMs can be found in Saitoh[1] . The transformations of the GLPMs are necessary, as they cannot be used directly in the OpenSees because of the gyro-element. It is done by fully fixing the one end node of the GLPMs as shown in **Fig. 1(b)** after which the gyro-element becomes a simple mass element.

The transformed GLPMs were applied in a SDOF system supported by a pile group[2] using transformed GLPMs in OpenSees. Dynamic response of the structural system with transformed GLMPs in both frequency domain analysis and time domain analysis shows total agreement with the response of the structure with GLPMs presented by Saitoh[2] .

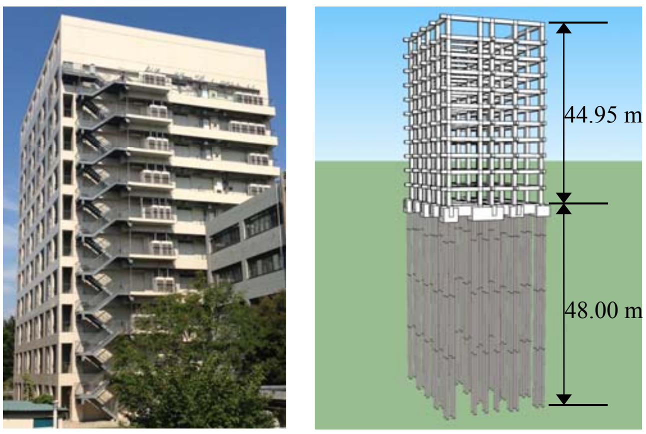

Fig. 2 The building of research and project of Saitama University and its schematic with beams, columns and piles.

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3. GLPMS IN A 3D MDOF SYSTEM

3.1 Selection of the structure

The building of research and project of Saitama University is considered for this study (Fig. 2). This is a 10 story building with the height of 44.95 m. The building is supported by a group of pile with the length of 48 m.

3.2 Determination of dynamic soil properties and FIM

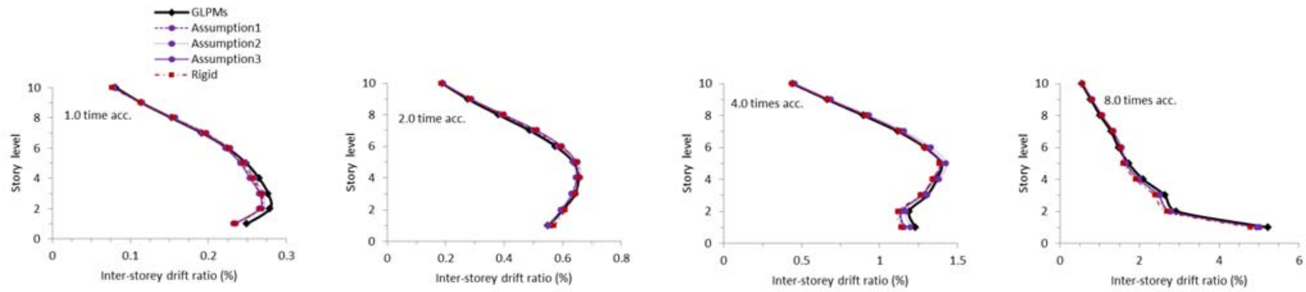
Conventional one-dimensional equivalent linear analysis is performed in DEEPSOIL to obtain the dynamic properties of soil and foundation input motion (FIM). Nigata 2004, earthquake was applied at the base layer of the soil and FIM was recorded at the top layer of the soil along with properties of layer at layer. FIMs are magnified by two, four and eight times to make the response of the building in inelastic region.

3.3 Estimation of IFs and simulation by GLPMs

The impedance function of the soil-foundation system were calculated and compared with GLPMs. IFs were calculated in the five directions, three mutually perpendicular directions and two rotational directions perpendicular to the two horizontal axes.

4. RESULTS AND DISCUSSION

Fig. 3 shows that inter-story drifts for the GLPMs, three assumptions of the frequency independent Kelvin-Voigt model and rigid foundation have no significant difference except slightly higher inter-story drift ratio for the lower stories of the building whereas the response of the foundation shows significant difference (**Fig. 4**) for all cases with magnified FIM. There is no displacement for the rigid foundation cases.



.**Fig. 3** Inter-story drift for magnified FIM with different assumptions of the foundation.

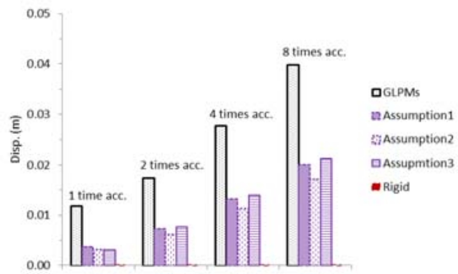


Fig. 4 Maximum displacement at the foundation with magnified FIM with different assumptions of the foundation.

5. CONCLUSION

Multi-story buildings supported by the pile groups show frequency dependent characteristics. The sophisticated GLPMs can be used efficiently to incorporate those frequency dependent properties in the conventional software platform. Differences in the inter-story drift ratio in the lower stories of the building are significant compared to the differences in the upper stories of the building.

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