別紙様式 5 (Attached Form 5)

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Seismic Performance Investigation of the Folded Cantilever Shear Structure Which Consists of Fixed and Movable Sub-Frames

可動支点と固定支点を有する片持ちせん断構造の耐震性能に関する研究

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A newly designed structure named folded cantilever shear structure (FCSS) is proposed as an alternative seismic isolation approach incorporating coupling method and base isolation method in one structure for improving earthquake resistant ability and seismic performance of mid-rise buildings. The proposed structure consists of non-isolated, which is named fixed, and fully isolated, which is named movable, sub-frames of similar heights, and these fully separated sub-frames were rigidly connected to each other by a connection sub-frame at the top part. This allows all three sub-frames to behave as a unique structure. In this manner, it is aimed to extend the natural period of the structure and to decrease the overall seismic responses.

It was found that the proposed structure is capable of extending natural period and minimizing accelerations, displacements and base shear forces simultaneously, when compared to ordinary structure which has the same number of storey. However, relative displacements, for the proposed structure without additional dampers, with respect to the base were obtained relatively higher. Therefore, additional viscous dampers were added between adjacent beams to connect both sub-frames with the aim of avoiding excessive displacements and increasing the damping ratio as well.

In this dissertation, dynamic characteristics of the proposed structure have been investigated theoretically and experimentally.

In chapter 1, a brief introduction about the previous works on coupled structures and coupling configurations are given.

In chapter 2, the detailed dynamic characteristics of an ordinary mid-rise building are introduced by reason of the ordinary building is taken as a comparison model for the proposed building. By taking both structure with similar height and characteristics, it is possible to explore whether the proposed model has shown any enhancement in terms of seismic performance.

In chapter 3, the proposed building named, folded cantilever shear structure, is introduced. The design principles and building configuration is elaborated by illustrative figure. Then the detailed dynamic characteristics of the proposed building are introduced for two different cases which are; folded cantilever shear structure without and with additional dampers. Simple equations are also derived to let us estimate the dynamic parameters of the proposed building for a given parameters. And natural frequencies, damping ratios, mode shapes and their relations with storey number is investigated.

In Chapter 4, numerical studies were conducted in order to verify the dynamic parameter characteristics and the theory of the proposed structure that is elaborated in the previous chapter. Three models, ordinary building and proposed building without and with additional dampers, were investigated through eigenvalue analysis and elastic dynamic response analyses under four exemplary ground motions, namely El Centro, Hachinohe, Miyagi and Taft earthquakes. The preliminary results were obtained confirming that the structural behaviour and seismic performance is upgraded in case of proposed model.

In Chapter 5, the seismic behaviour investigation of the proposed structure is elaborated by applying a set of experiments to obtain dynamic parameters such as natural frequencies, damping ratios and mode shapes. Shaking table test were also conducted by using 16-storey vibration model under same ground motions used in numerical studies.
Since the experimental vibration model is not a scaled model, the results were also compared and verified by analyzing experimental vibration model on ABAQUS, well-known finite element software. In both studies, the proposed structure performed substantial improvement in reducing seismic responses when compared to ordinary structure of similar height.

In chapter 6, the proposed structure is modified to come up with an idea avoiding structural irregularity with a symmetrically designed building of FCSS consisted fixed - movable - fixed sub-frame configuration. Similar to the first configuration of the proposed structure, the seismic behavior of the modified model is elaborated due to numerical and experimental analysis. In general terms, the modified structure provides better outcomes such as symmetrical configuration, providing more space for damping placement and better seismic performance. Therefore, the modified model is set as the final configuration of proposed structure to be vibration model for the numerical studies of real-scale building investigations to be design as mid-rise building. This modified model is also tested through numerical and experimental analyses to clarify whether it has an increasing effect on seismic performance or not when compared to old type of FCSS which has only two sub-frame configuration, fixed - movable sub-frames. An introduction to real-scale building investigations are given, including the preliminary seismic behavior studies on the real-scale model.

In Chapter 7, the conclusion is given.