THE "STONEHENGE 21" PROJECT

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ABSTRACT :

The paper reports on the major features of "Stonehenge 21", a conceptual design which took an honorary award from the International idea competition of the Japan Society of Seismic Isolation (2004). It incorporates the idea of combined seismic protection of a *complex of buildings* based on passive response control system including base isolation and supplemental dampers. The proposed configuration resembles the ancient megalithic Stonehenge in the UK. The unifying top ring in combination with the modern response control technologies allows to more efficiently mobilize the strength, stiffness and damping resources of the individual buildings. The expected merits of the concept are discussed and analyzed. The complex is conceived as a town landmark. The top ring provides a panoramic 360-degree view and more importantly, provides an *alternative route of evacuation* in case of emergency (fire or terrorist attack in any the component buildings).

KEYWORDS: Seismic isolation, damping systems, seismic protection

1. INTRODUCTION

A survey on the Japanese construction and design practice showed that the number of buildings with seismic (base) isolation and damping systems had increased dramatically following the 1995 Kobe earthquake [Clark, P. et al., 1999]. This new trend could be attributed to various technical, economic, political and cultural factors. However, many of the responding companies believed that the major reason was the fact that a part of the society had lost its confidence in the conventional construction methods, which were not capable of preventing the huge damage and losses incurred by the recent strong quake.

According to [Martelli, 2000] about 2000 projects worldwide have implemented some type of modern seismic protection systems up to year 2000. The seismic isolation and passive energy dissipation systems have reached a stage of maturity that makes them reliable and efficient technologies for seismic protection of buildings, bridges, industrial facilities and masterpieces of the cultural heritage.

In 2003 the Japanese Society of Seismic Isolation (JSSI) announced an international idea competition to mark the 10th anniversary of its foundation. The topic of this competition was formulated as follows: "The city you want to live in, the building you want to live in". The intent was to encourage and promote the implementation of emerging technologies such as seismic isolation and response control that could respond to the growing needs of modern society for safe, comfortable and sustainable places to live according to JSSI. The herein reported conceptual design entitled 'Stonehenge 21" got one of the honorary wards in strong competition with the outstanding proposals of leading Japanese design and construction companies.

2. DESCRIPTION OF THE PROPOSED CONCEPT

The seismic isolation has sofar been focused mainly on protection of separate free-standing buildings and facilities. In tall buildings the efficiency of base isolation decreases due to the amplification of the input accelerations along the height. The higher aspect ratio also involves certain problems with the uplift resistance related to the larger overturning moments at base. These issues impose certain economic and esthetical limitations on the expansion of the seismic isolation technology.

Our proposal develops the idea of combined seismic protection of a complex of buildings that interact with each other so that the overall dynamic response of the complex is improved compared to the response of the separate component building. In order to fully mobilize the strength, stiffness and damping resources of the component buildings, a unifying ring on their tops should be included. This configuration was discovered in the ancient megalithic site of Stonehenge in the UK - an ensemble of circumferentially arranged huge vertical stone piers connected by horizontal stone blocks forming a ring on top (Fig. 1).

Figure 1. Partial elevation view of the ancient Stonehenge

The conceptual design named “Stonehenge 21” consists of 12 major buildings (V-buildings) arranged at uniform spacing along a circle and connected by another 12 horizontal segments (H-buildings) that form a ring on the top (Fig. 2). Each V-building has seismic isolation system at its base. Each H-building is supported by rubber bearings on the two adjacent V-buildings.

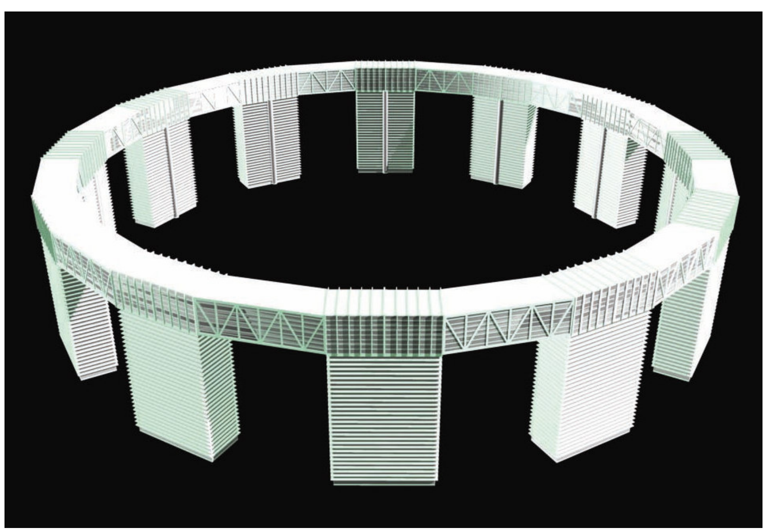

Figure 2. Perspective view of “Stonehenge 21”

Damper devices are also inserted at the interface between each V- and H-building for added energy dissipation at this level (Fig.3). To avoid problems with thermal stresses and differential settlements of the foundation system, expansion joints should be provided between the H-buildings, e.g. at the centerlines of the V-buildings. These expansion joints should be equipped with lock-up devices (hydraulic couplers) which tolerate static displacements but create an integrating ring when a seismic event or wind storm induces vibration of the complex.

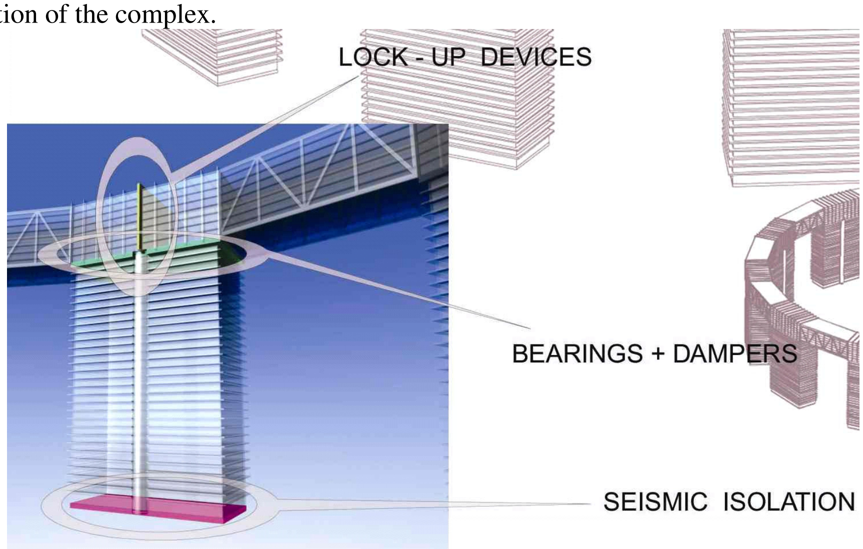

Figure 3. Components of the response control system

The top ring allows for dynamic interaction of the V-buildings so that larger aspect ratio and larger number of stories become possible compared to a conventional single base-isolated building. Ideally, if well optimized in terms of masses, stiffness and damping, the top ring could play the role of a heavy TMD (Tuned Mass Damper) for the twelve V-buildings.

3. MERITS AND EXPECTED BENEFITS

3.1. *Architectural Merits*

The complex is conceived as a town landmark. It creates an "envelope" for the public space within the circle formed by the twelve V-buildings, which could be used as a park, open-air museum or for other purposes. The top ring provides a panoramic 360-degree view over the town and more importantly, provides an alternative route of evacuation in case of emergency (fire or terrorist attack in any of the V-buildings). Fig. 4 illustrates the idea of horizontal evacuation passage, which was highly appraised by the competition reviewers.

3.2. *Structural Merits*

From a structural viewpoint the dynamic response will be more predictable and reliable as the structural system is symmetrical about the central point of the circle. Therefore, it is not sensitive to the direction of the lateral loads. Due to the connecting top ring the component buildings do not behave as vertical cantilever beams. Therefore, it is not compulsory to provide similar stiffness and periods of vibration in the two major directions of each building. The individual buildings will benefit from the synergy and joint resistance of all components of the complex. Furthermore, a local failure such as formation of soft storey or localized plastic hinging in any of the V-buildings would be less detrimental due to the lateral force redistribution and branched load path – factors that are essential in the multi-hazard design approach.

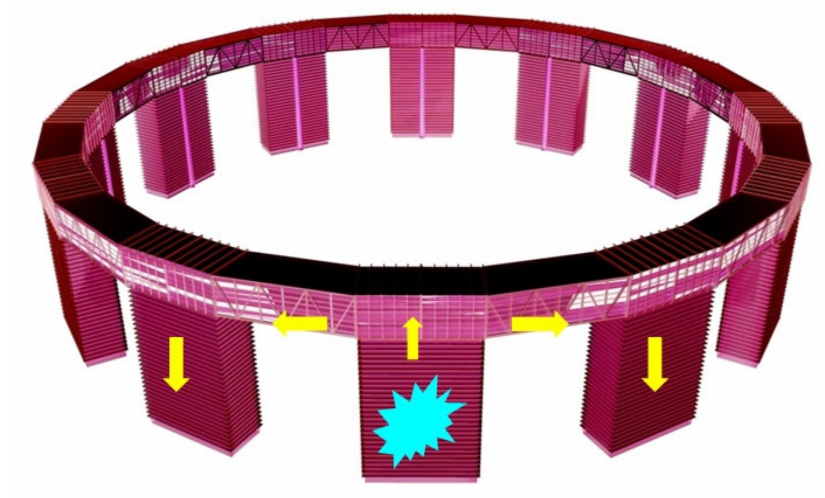

Figure 4. Illustration of the alternative evacuation passage

3.3. *Economic merits*

The larger number of stories in the V-buildings compared to a conventional free-standing isolated building with the same in-plan dimensions and the additional floor area provided by the H-buildings forming the top ring would result in better financial feasibility for this type of seismic protection system.

3.4. *Social benefits*

The proposed arrangement of buildings in the complex is a symbol of joint defense and good example for sharing of resources and teamwork against natural disasters. It would also allow for better integration of the various occupancies that are typically present within a conventional high-rise building. The availability of an alternative emergency egress route will enhance the feeling of safety of all building users.

4. POSSIBLE IMPLEMENTATION TO NON-ISOLATED BUILDINGS

The seismic isolation is a powerful technology for protection of the built environment and contents/equipment, but its use, however, might be restricted in some cases where the site conditions involve soft soil layers that tend to adversely amplify the low-frequency content of the ground motion. Such conditions could be seen in many big Asian cities where the conventional deep pile foundation is used for most of the high-rise buildings. The authors believe that such soil conditions are not prohibitive to the implementation of the general concept and configuration of the “Stonehenge 21” project. Most of the above-mentioned merits will be available even if there is no seismic isolation at the base of the V-buildings. Numerical analyses and parametric studies are in progress aiming to estimate the efficiency of interaction and lateral force redistribution between the various components of the complex.

5. CONCLUSIONS

The "Stonehenge 21" project is not a pure analogy to the ancient megalithic complex in UK. When soft links and energy dissipating devices are properly designed and inserted at the interfaces of the component buildings, enhanced seismic safety could be achieved. The proposed "air corridor" on the top, providing an emergency evacuation passage was specially noted by the Screening Committee of the competition held by JSSI.

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