SEISMIC ISOLATION OF TORSIONALLY COUPLED MACHINE FOUNDATION CONSIDERING SOIL-STRUCTURE INTERACTION

by

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ABSTRACT

Machine foundations are inevitable components of any industrial infrastructure which helps in distribution of the machine loads and mitigation of vibrations developed due to the rotating machine parts. Soil conditions and the types of foundation which support these machines play an important role in ensuring safe design and performance of different machines. Framed-type machine foundations also known as turbo-generator (TG) foundations are the common supporting system for rotary machines of medium to high-speed (Barkan, 1962; Arya et al., 1979; BIS, 1992; Srinivasulu and Vaidyanathan, 1980; Bhatia, 2008). In general, the permissible displacement amplitude of vibration for the framed-type machine foundations supporting rotary machine is very low (Blake, 1964; Baxter and Bernhard, 1967; Richart et al., 1970; Prakash and Puri, 1988; BIS, 1992; ACI, 2004; Das and Ramana, 2010). When vibration control devices (base isolation techniques) are used, the design approaches for the machine foundations considering torsional effects (due to eccentricities between center of rigidity and center of mass) are still in the development stage. Especially, the effects of flexibility of underlying soil in combination with torsional coupling is ignored in the designs. In machine foundations, dynamic loads always exist and the energy content of this force is transmitted to the supporting soil through foundation system. This energy travels in all directions into the soil and part gets absorbed by the soil itself, part reflects back to the foundation and thereby into the machine. This cyclic process initiates Soil-Structure Interaction (SSI), which significantly influences the dynamic response of the machine foundation (Mayerhof, 1953; Gazetas, 1983; Wolf, 1997; Biswas and Manna, 2018). The present research work investigates the effects of base isolation devices used in torsionally coupled machine foundations while duly considering SSI in to account.

Observations of damages on structures after recent earthquakes have shown the importance of torsional vibrations, induced by lateral seismic ground motions. Eccentricity between the center of mass (CM) and the center of rigidity (CR) may lead to torsional coupling in framed structures (Danisch and Labes, 1976; Reinhorn et al., 1977; Eisenberger and Rutenberg, 1985; Chandler and Hutchinson, 1986; Kelly, 1986; Rutenberg and Pekau, 1987; Chandler and Hutchinson, 1992; Jiang and Hutchinson, 1993; Jangid and Datta, 1995; Jangid and Kelly, 2000; Kilar and Koren, 2009; Matsagar and Jangid, 2010; Trifunac, 2013). Asymmetries are quite common in framed-type machine foundations supporting

rotary machines as it consists many cut-outs (openings) in deck slab. Also, the layout of equipment and its accessories (such as heavy turbine, generator, gear box, equipment oil system, condenser etc.) on deck slab are quite complex and its arrangement are also not symmetrical. This would lead to prevalence of torsional coupling in most turbine machine foundations. In addition, geometrical imperfections in the form of initial curvature or bend, i.e. out-of-plumb are possible during construction of slender columns. Slender columns are very common in the framed-type machine foundations supporting rotary machines, and hence the imperfections in the form of initial bend are possible. These initial geometrical imperfections in general, reduce the load-carrying capacity of the structure/foundation under static loads. In addition, these imperfections may alter the stiffness of columns, which may eventually affect the dynamic response of structures/foundations (Chajes, 1974; Celep, 1985; Souza, 1987; Yaoshun et al., 1998; Dubina and Ungureanu, 2002; and Sovizi et al., 2010; Sharma et al., 2014; Jain and Rai, 2014; Shayan et al., 2014; Cardoso and Rasmussen, 2016; Monsalve-Giraldo et al., 2017; Marinca and Herisanu, 2018; De Domenico et al., 2018; Dhar et al., 2018). Hence, the main sources of asymmetries in framed-type machine foundation considered here are due to variation in the stiffness provided by columns (construction defects) and due to uneven distribution of machine mass on the deck slab.

Improper functioning of sensitive equipments, disturbances to people and visible structural damage may occur due to dynamic effects of machines, especially in industries (ACI, 2004). The base isolation concept is mainly used to decouple the machine vibrations and seismic ground motion from its foundation. Using the base isolation technique, the structure is isolated from the vibrations by insertion of flexible layer, which is formed by elastomeric and/or sliding bearings. Such flexibility elongates time period, thereby reduce seismic forces. Moreover, the bearings provide additional means of energy dissipation through high damping (Jangid and Datta, 1995; Jangid and Kelly, 2000; Matsagar and Jangid, 2005; Bhat and Paul, 2016; Konstantinidis, 2018; Terazawa and Takeuchi, 2018). The aim of vibration isolation of machine foundation is to prevent transmission of vibrations from the machine or from ground. The foundation is designed to avoid resonance with the machine vibrations and also against seismic ground motions. However, in most cases, the effect of soil flexibility and torsional effects are ignored in the machine foundation design. The proposed doctoral research will greatly contribute in the advancement of current knowledge in the design of machine foundations and vibration mitigation therein, considering the effects of torsional coupling, geometrical imperfection and SSI.