COMPARISON OF STRUCTURAL RESPONSE FOR VARIOUS INPUT EXCITATIONS

CASE STUDY = HIGHWAY BRIDGE BENT

In order to obtain a realistic set of results, a single-column bent of a highway viaduct (which is a part of a freeway) is used as the reference structure.

Nonlinear response history analyses are applied considering:

CASE – 1: Horizontal motion w/o P-D effect;
CASE – 2: Horizontal with P-Deffect
CASE – 3: Horizontal + vertical motion
CASE – 4: Horizontal - vertical motion
CASE – 5: Horizontal + vertical motion + tilting

IMPACTS OF ROTATIONAL GROUND MOTIONS ON STRUCTURES

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Motivation

- Ground rotations can reach a few degrees in the near-field zone (e.g. Pacoima Dam – Northridge Eq.).
- Current engineering practice is not devised to deal with few degrees of ground rotations.
- Coupling of rotational component with translational components of ground motion may impose amplified seismic demands on structures.

Summary of Research

- In order to account for rotational motions in design and performance assessment of structures, governing equation of motion for multi-component—horizontal, vertical, and rotational—excitation is developed.
- The expanded equation includes P-D components (an additional overturning moment at the base of the inverted oscillator created by gravitational acceleration on the oscillator’s mass when it is displaced from its original position) from ground tilting and vertical acceleration in addition to inertia forces due to angular and horizontal accelerations.
- Using an idealized model of a bridge bent, inelastic structural response parameters are computed considering single and multi-component excitation; and it is demonstrated that higher ductility demand may ensue when vertical and rotational components are coupled with horizontal component. Ignoring this coupling may lead to significant underestimation of seismic demands from structural systems.

Equation of Motion (Horizontal Motion + Tiling)

Equation of Motion (Horizontal Motion + Vertical Motion + Tiling)

Progression of Dynamic Collapse Due to P-D Effect

Dynamic instability (or collapse) can be initiated if the energy of the multi-component excitations is large enough to carry the system inelastically in one direction.

Conclusions

- Inclusion of vertical and tilt components results in additional forcing functions and enhanced P-A effects. The resulting amplified seismic demand and eroded stiffness may adversely influence the displacement (ductility) demand and dynamic stability. Therefore, for structures susceptible to high-intensity vertical shaking and/or ground tilting, multi-components effects should be considered in their seismic design or performance assessment.
- Compared to vertical component, tilt component of the motion has more impact on the translational response of the system. Few degrees of dynamic ground tilting can easily double the overall system response. This difference will be more pronounced for the tall structures since the inertia force due to the angular acceleration is directly proportional to the effective height.

