A VERTICAL ACCELERATION FAILURE IN MANAGUA

by
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The Managua, Nicaragua, earthquake of December 23, 1972, caused extensive damage and loss of life. It has been the topic of numerous reports and papers written to emphasize the poor as well as the good performance of significant structures in the area. This paper deals with a small structure in downtown Managua, a service station, that demonstrated the very important lesson of the failure of long flexible prestressed beams due to vertical acceleration.

The structure is a two story concrete frame with infill clay tile masonry walls and second story exterior precast panels (Photo #1). Two 5.2 m. by 7.9 m. concrete canopies are supported on pairs of .35 m. wide x .60 m. deep post-tensioned girders spanning 13.8 m. from the main structure to a flexible perimeter concrete frame. Primary damage consisted of shear failures of the infill walls, substantial strong axis hinging of the post-tensioned canopy girders at their outboard juncture with the canopy slabs (Photo #2) and weak-way hinging of the perimeter columns on the canopy girder lines (Photo #1).

In an attempt to verify the primary cause of girder hinging, a response spectrum and modal time history analysis were performed on a three-dimensional elastic model of one canopy structure using the ESSO refinery record. The model consisted of one pair of the post-tensioned girders, a finite element representation of the canopy slab, a one bay frame of the perimeter wall, the first story framing of the main structure including the second floor slab and transverse supports at the second floor to provide a proper boundary condition. The first two modes of the structure were vertical with the girders in and out of phase with periods of 0.18 and 0.17 seconds. The third and fourth modes were longitudinal and transverse with periods of 0.14 and 0.13 seconds, respectively. The analysis, including gravity effects, clearly showed that the girder hinging could be attributed to vertical acceleration occurring within the first 3 seconds of vertical excitation. At that time, the response due to longitudinal excitation produced moments of a smaller order of magnitude. The maximum response due to longitudinal excitation occurred after 6 seconds when the elastic model is no longer valid. The analysis also showed that the perimeter column hinging occurred after the girder hinging.

These results validate the concern of many engineers that long, rather flexible prestressed concrete beams, where the gravity loads are largely balanced by the prestressing, are highly vulnerable to damage and failure from vertical accelerations.

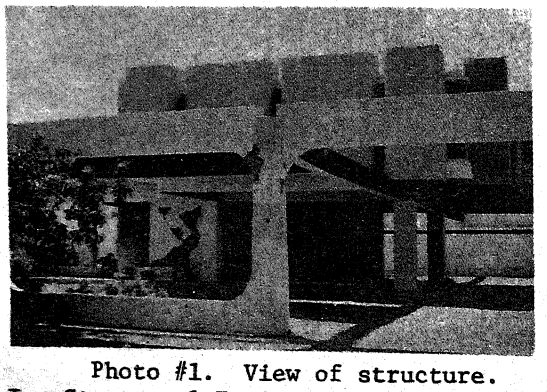

Photo #1. View of structure.

Photo #2. Girder hinge.

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