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**Motivation**: As an example, near-fault vertical ground motions may lead to tensile forces on the bridge columns during short time intervals, leading to negligible contribution of concrete to shear capacity after cracking. On the demand side, axial forces that are not taken into consideration, such as those due to vertical excitation, may lead to an increase in the moment capacities, resulting in greater shear forces than expected. (Section 1.1.1)

**Objectives**: The main objective of this study is to investigate the effect of axial force produced by the vertical component of the ground motion on the behavior of bridge columns, especially on shear strength degradation. The outline of specimen design and input candidates were determined based on the parametric study results. Dynamic tests of two specimens were conducted and the results imply that vertical acceleration has the potential to degrade the shear capacity of an RC bridge column. (Section 1.1.2)

**Methodology**: Results of these analyses were utilized as a guidance to select the ground motions, column geometry, and reinforcement, and the set-up of the shaking table tests. However, since the axial force is the only important parameter that is significantly affected by vertical excitation, it can be concluded that the differences between models Types 1 and 2 are not important for the purposes of this study. For shear strength demand to capacity ratio (Maxdcr) values, the order in estimates of different codes is Eurocode < ACI ≤ SDC < CSA, on average. For shear strength reduction (Red) values, the order in estimates of different codes is CSA < SDC < ACI ≈ Eurocode, on average. CSA takes the effect of axial force into consideration by using axial strain at the centroid of the section, resulting in differences in the shear capacity predictions for different ground motions and different ARs in cases without vertical excitation, since the axial strain at the centroid of the section is not only affected by the axial force but also by the bending moment. A parametric study was conducted on columns designed with the modified effective circular section of Prototype 1 (ACB) and subjected to ground motions to evaluate the effect of vertical excitation. However, since the axial force is the only parameter that was significantly affected by the vertical excitation, it can be concluded that the differences between Types 1 and 2 (especially Type 2-1) may not be important for the purpose of this study. CSA, however, takes the effect of axial force into consideration by using axial strain at the centroid of the cross section, resulting in differences in the shear capacity predictions for different ground motions and different ARs, even cases without vertical excitation. Due to limitation of facilities, to date only a few shaking table tests have been conducted to examine the effect of vertical acceleration on bridge columns. To perform tests on the UC Berkeley shaking table at the Richmond Field Station (RFS), 1/4-scale bridge column specimens, instrumentation, and input sequence were prepared to investigate the response of a bridge column subjected to the horizontal and vertical dynamic excitations. Among the four ground motions that were selected based on the analytical study, GM7 is the most suitable for dynamic tests with vertical excitation considering the shaking table characteristics. The dynamic tests to examine the effect of vertical excitation on shear strength of RC bridge columns were designed within capacity of the UC-Berkeley shaking table located at the Richmond Field Station. This chapter presents the computational models developed in order to predict the response of the tested bridge columns. (Chapters 2, 3, Sections 6.1, 6.2, 6.3)

**Results**: The rationale for not having the ratio of stiffness equal to the square of the ratio of period was because the tested column represented a 2DOF system in the lateral direction, with coupling between the translational and rotational modes. The maximum acceleration at the top of the column or on the mass blocks did not increase linearly with that on the table or the input intensity for two reasons First, the lateral stiffness of the column decreased with increasing level of intensity; second, the base shear capacity of the column was reached at the higher intensity levels. In contrast, the acceleration histories in the Z-direction were almost the same on the table, along the column height, and on top of the mass blocks. Comparison of bending moment histories at the base and top of both of the specimens indicated that they were opposite in sign during the strong part of the excitation of all the intensity levels, suggesting that the columns were in double-curvature. Note that three 125%-scale resulted in similar maximum moment values, suggesting that the axial force variation did not affect the bending moment noticeably. From 95%-scale tests, the decrease in lateral stiffness had a directional difference, implying that the damage was not symmetric on the north and south. In the axial force-vertical displacement relation, no significant decrease in stiffness was observed. As a result of flexural yielding both at the top and bottom of the column in double curvature, the shear force reached shear capacity, which would not take place if yielding was occurring at the bottom and the moment at the top was smaller than the yield moment; therefore, shear cracks occurred. Note that the diagonal cracks did not appear during 125% ‘X only’ test as many as those in 125% ‘X+Z’ tests, supporting the observation that the concrete contribution to shear strength was reduced due to the presence of axial tension. The longitudinal strain response was measured at the four reinforcing bars on the north, south, east, and west sides. As observed in the curvature responses, double-curvature was confirmed by the longitudinal strain on the north and south sides (since the phase angle between the time histories of the strain measurements was shifted along the height during the main excitation). For the east and west sides, the abrupt change in tensile strain due to axial tension was remarkable. The axial force significantly affected the strain histories on the east and west, and one of the peaks in each history appeared at the tension peak. For the input motion in X- and Y-directions, the acceleration histories recorded on the shaking table during 50% to 125%-scale tests were used. The computational models containing BWH and NLBC elements provided similar results Both models were successful in capturing the shear force and lateral displacement history measured during the tests. (Chapters 4, 5, Section 6.4)

**Conclusions**: Reduction in the concrete strength was also evidenced by the comparison of shear cracks in the 125%-scale horizontal only and horizontal and vertical tests. Tensile force due to vertical excitation reduced the shear strength and increased shear cracks. Developed computational models were successful in capturing the shear force and displacement histories measured during the tests. However, because vertical displacement produced by the axial force was the end result of this investigation, which does not change the interaction of axial and shear response; such a detailed finite element model was not considered. Both the ACI-218-11 and SDC equations captured the shear strength degradation due to axial force. The developed shear springs element implemented in OpenSees fulfilled the objectives of the computational modeling for simulating the effect of the axial force on the shear strength.(Section 7.2)