I-623 DUCTILITY MEASUREMENT FOR THE TESTING OF BRIDGE PIERS

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INTRODUCTION

The inelastic response of bridges in codes worldwide is generally estimated by means of a ductility based approach. While the effect of foundation flexibility is often taken account of in the estimation of the strength of structures, it has often been ignored in the estimation of the maximum displacements to which the pier test specimen should be subjected. In this paper it is shown that ignoring this flexibility in the estimation of the displacements to which a test specimen should be subjected is inconservative. The effect of elastic displacements apart from those of the member in a test frame also discussed.

DIFFERENCE IN SYSTEM AND MEMBER DUCTILITY

Prediction of the expected member displacement ductility demand is generally based upon rules derived from dynamic time-history analyses of single degree of freedom oscillators. The initial stiffness of an oscillator represents the stiffness of a whole structure-foundation system. In the testing of model bridge piers, the displacements to which the specimen is expected to be able to be deformed without a large loss of strength has often been calculated from the stiffness of the pier itself and the system displacement ductility. However, the actual displacement ductility demand of a real pier, μ_m, will be greater than that from the system, μ_s, as shown below because of the effects of foundation flexibility.

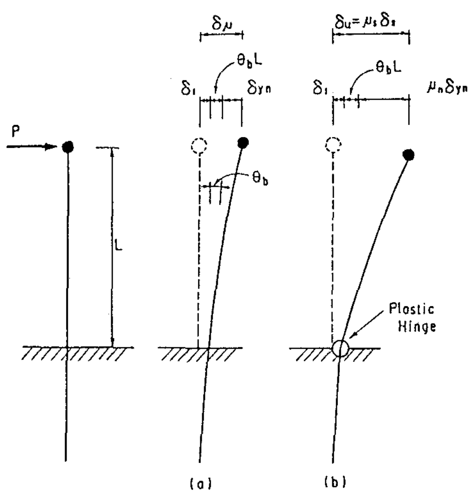

Figure 1. Difference between Member and System Displacement Ductility

The yield displacement, d_y, of the pier shown in Figure 1a is given by Equation 1.

$$d_y = d_1 + \theta_b L + d_{yn} \tag{1}$$

where d_1 is the horizontal movement of the footing, θ_b, is the rotation of the footing, L is the height of the pier and d_{yn} is the yield displacement of the member alone. If it is assumed that the pier is the only inelastically deforming element in the system and that its hysteresis shape is elastic-perfectly plastic, the maximum displacement, d_u, shown in Figure 1b is given in Equation 2.

$$d_u = d_1 + \theta_b L + \mu_m d_{yn} \tag{2}$$

As the system displacement ductility, μ_s, is defined as d_u/d_y, the member displacement ductility, μ_s, from Equations 1 and 2, will be given by Equation 3.

$$\mu_m = \mu_s + (\mu_s - 1)(d_1 + \theta_b L)/d_{yn} \tag{3}$$

In this formula it may be seen that the member displacement ductility, μ_m, will always be greater than or equal to the system displacement ductility, μ_s, with the amount of this difference depending on the amount of foundation flexibility and the size of the ductility demand. In the case of infinite foundation rigidity, the member displacement ductility, μ_m, is equal to the system displacement ductility, μ_s.

System displacement ductilities greater than or equal to 5 are often considered to be necessary in testing in countries such as Japan and New Zealand. As many real piers are stiff and are situated on soft ground, testing may need to be carried out to displacement ductilities greater than the assumed system displacement ductility level.

In the same way that the displacements of real piers are increased by foundation flexibility, test specimens generally also experience larger displacements than that expected from member deformation alone. The flexibility of the load frame and bolts connecting a specimen to the frame was 38% of the member yield displacement in some tests carried out on steel specimens at the University of Canterbury [1]. The yield displacement will always be overestimated if it is calculated from the stiffness found in testing.

The yield displacement of a steel specimen may be calculated even before the test has been started based on calculated section dimensions and the results of yield tests [1], however, for reinforced concrete specimens the member yield displacement is more difficult to predict. A conservative approach for such specimens is to assume that the member yield displacement, d_{yn}, is equal to that obtained directly from the tests. The required member displacement ductility should then be calculated using Equation 3 with realistic foundation flexibility parameters in order to determine the maximum displacement which should be attained before large amounts of strength are lost.

CONCLUSIONS

In this discussion paper it was shown that the member displacement ductility demands of bridge piers may be considerably larger than the displacement ductility demands of the system which includes the effect of foundation flexibility. The effect of flexibility of the test frame will also affect the yield displacement. These effects should be considered in order to ensure that results from model testing may be compared realistically with the expected behaviour of a real pier.

REFERENCES

1. MacRae G. A., Carr A. J. and Walpole W. R., "The Seismic Behaviour of Steel Frames", Research Report 90-6, Dept. of Civil Engineering, University of Canterbury, New Zealand, 1990.