EMERGENCY REPAIR OF RC BRIDGE COLUMNS SUBJECTED TO EARTHQUAKES

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Key words: Emergency repair, concrete columns, CFRP, confinement, shear capacity, drift capacity.

INTRODUCTION

Past effort in the seismic design of concrete bridges has been on detailing of bridges to prevent collapse. During earthquakes, reinforced concrete bridge columns are designed to undergo cracking, spalling, and yielding of steel and provide significant rotational capacity at plastic hinges so that the integrity of the overall structure is maintained. With proper design and construction, this objective can be met. However, the serviceability of the bridge after the earthquake is in question. The level of damage to different columns of a bridge varies depending on the intensity of the ground shaking, type of earthquake, and the force/deformation demand on individual members. Based on the inspection of the damaged columns engineers have to determine whether the bridge is sufficiently safe to be kept open to traffic. They should also recommend repair methods for the columns. Any delay in opening of the bridge to traffic can have severe consequences on the passage of emergency vehicles, detour lengths, and traffic congestion in the area. Rapid and effective repair methods are needed to enable quick opening of the bridge to minimize impact on the community.

In this study, the middle bent (Fig. 1) of a large-scale two-span bridge model, which was damaged to the highest repairable level in the previous tests, was repaired using CFRP wrapping. At this level of the damage, many spirals and longitudinal bars are visible, some of the longitudinal bars are beginning to buckle, and the edge of concrete core is damaged. No bars are ruptured.

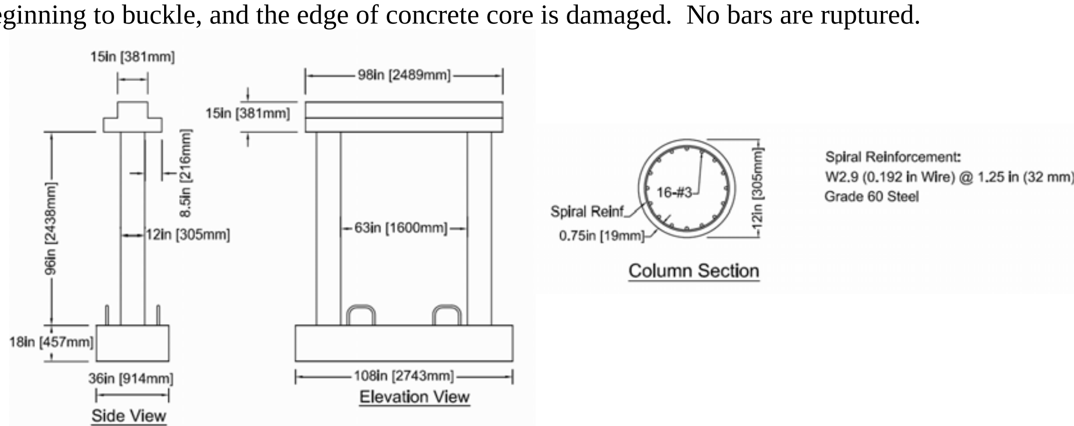

Figure 1. Middle bent (Bent-2) details

REPAIR DESIGN

The repair system was designed with the objective of restoring confinement and shear strength of the columns by using unidirectional CFRP jacketing.

Hans Beushausen, Proceedings of 2nd International Conference on Concrete Repair, Rehabilitation, and Retrofitting (ICCRRR 2008), Cape Town, South Africa, 24 - 26 November 2008, © CRC Pres/Balkema. Used with permission.

Based on the California Department of Transportation (Caltrans) provisions, for regions inside and outside a plastic hinge region, it is necessary to provide a minimum confinement stress of 300 psi (2.07 MPa), and 150 psi (1.03MPa), respectively at a radial dilating strain of 0.004.
Using Caltrans criteria for seismic shear design for ductile concrete members, the required thickness for the jacketing, t_j, is determined as:

$$t_j = \frac{V_o/\phi - (V_c + V_s)}{\pi/2 \times 0.004 \times E_j \times D} \tag{1}$$

Where V_o is overstrength shear, V_c is the concrete shear capacity, V_s is the shear strength provided by the spirals, E_j is CFRP modulus of elasticity, D is column diameter, and ϕ is 0.85.
Since spiral experienced a maximum strain for 74% of yield, and some of cracks were not repairable inside the core, V_c, and V_s were neglected. V_o was assumed to be associated with the maximum moment achieved in the pre-repair tests.

REPAIR PROCESS

The entire repair process took approximately 30 hours spread over four days, and it involved straightening the columns, concrete chipping, pressurized epoxy injection of the cracks, fast set concrete patching, surface preparation for CFRP wrapping, CFRP wrapping, and curing.

REPAIRED BRIDGE PERFORMANCE

To allow the comparison of the responses with respect to lateral load capacity, service level stiffness, and the ductility capacity, the measured envelopes were idealized by elasto-plastic curves. The results show that the capacity of the bent was restored completely after repair. The ductility capacity of the bent was also restored. Although the achieved ductility capacity for post-repair tests is greater than the ductility of pre-repair tests, but it must be noted that the calculated ductility for the pre-repair tests is based on maximum displacement at the highest repairable level, and not failure. In addition, 87% of the elastic stiffness of the bent was restored by the repair.
The maximum drift ratio in the pre-repair tests, and that of post-repair tests at failure were 10.4%, and 12.75%, respectively. It can be concluded that the ultimate drift capacity of the repaired bent was comparable to that of the original bent.

CONCLUSION

Based on the achieved data from testing the repaired model, the following conclusions are made:

- The repair design method, providing minimum confinement pressure for 300 psi (2.07 MPa), and providing plastic shear strength, was effective and appropriate.
- The repair process was practical and may be used for emergency repair of earthquake damage concrete columns.
- The repair restored the strength, ductility capacity, and drift capacity of the model completely, and restored the service level stiffness up to 87% of the original stiffness.

Although the jacketing system was cured for only 54 hours (24 hours of elevated heat and 30 hours of ambient lab temperature), the jacket system had the modulus of elasticity equal to specified value after one week curing. The minimum ultimate strain was less than specifications, but it was larger than the maximum design strain. Note that the specified curing time for CFRP is seven days.

REFRENCES

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