AN EXAMPLE OF EPOXY MORTAR REPAIR OF A REINFORCED CONCRETE BEAM-COLUMN JOINT

by
R. Michael McCafferty[I] and Martin L. Moody[II]

SYNOPSIS

The dependability of a beam-column joint repaired with an epoxy mortar is investigated. A full-size specimen was tested to failure by dynamic loadings. Then, it was repaired and again tested dynamically to determine the reliability of the repair. This limited investigation indicates that the type of repair reported may contribute to catastrophic failures in a real structure subjected to high energy dynamic loadings.

INTRODUCTION

Once a building has been damaged by a severe earthquake or any other source, the question arises as to whether the structure should be repaired or removed. To answer this question, one must examine both the economic and engineering feasibilities of restoring the structure. This paper investigates one aspect of engineering feasibility with respect to repair. During a series of dynamic tests of reinforced concrete beam- (12" x 18" x 72") column (12" x 15" x 162") specimens at the United States Department of the Interior, Bureau of Reclamation, Engineering and Research Center, Denver, Colorado, it was decided to repair one of the specimens. Personnel, skilled in the use of epoxy mortars to repair concrete members, repaired the joint region of a specimen which had been tested to failure. The mortar used in the repair was a sand and epoxy mixture[III] and was hand tamped into place after the loose concrete had been removed from the joint region. The original specimen had been subjected to a series of dynamic tests at three different energy levels with the final test causing extensive damage. To determine the effectiveness of the restoration, the repaired specimen was subjected to a similar series of tests. These tests indicated that the specimen was restored to a level of stiffness suitable for normal working loads. However, the high energy dynamic test caused a brittle type failure which could have been disasterous in a real structure.

SPECIMEN AND TESTING PROGRAM

The beam-column specimen was cast in three parts with the beam at the mid-span of the column forming a "T". The column was reinforced with 8 number 8 bars, and the beam was reinforced with 4 number 8 bars top and bottom. The transverse reinforcement consisted of stirrup-ties, made of number 3 bars, spaced at 7 inches in the beam, and hoop-ties, made of

---

[I] Civil Engineer, Department of Transportation, Federal Railroad Administration, Washington, D.C.; formally Structural Engineer with Bureau of Reclamation, Division of General Research, Denver, Colorado

[II] Associate Dean of Engineering and Applied Science, University of Colorado, Denver, Colorado

[III] Trade names and mix proportions are available on request.

number 3 bars, spaced at 8 inches in the column. Through the joint region, the spacing of the column hoop-ties was reduced to 4 inches. The concrete in the beam had a strength of 3,400 psi and a modulus of elasticity of 2,800,000 psi, and the concrete in the column had a strength of 5,100 psi and a modulus of elasticity of 3,500,000 psi. The order of placing the concrete was such that the beam concrete was placed in the column section at the joint. Thus, it was mainly beam concrete that was removed from the joint region and replaced by epoxy mortar in repairing the specimen. The epoxy mortar had a strength of 12,200 psi and a modulus of elasticity of 2,600,000 psi. Thus, the moduli of elasticity for the concrete and epoxy mortar were similar, and the strengths varied by a factor of four. In repairing the specimen, damaged concrete within the joint region was removed down to the reinforcing steel with an air operated chisel. Then, the surface was cleaned with air and coated with epoxy. The epoxy mortar was packed into place with the use of hand tools and the entire surface was built up in layers until the original surface was reached. Then, plastic coated plywood forms were placed around the joint to hold the mortar until it hardened.

A 50,000 pound force electro-hydraulic vibration system, which was described in an earlier paper by the first author[IV], was used to test the specimen. The tests consisted of two transient loadings, which were scaled versions of the 1940 El Centro earthquake, and a shakedown or fatique test to failure. The first test was a small energy transient which was designed to produce minor cracks in the beam and column, and the second test was a large energy transient designed to produce an "X" crack pattern in the joint. The final test was accomplished by setting the specimen in resonant frequency and holding it there until extensive damage was observed. During these tests, a 1,267 pound-mass was attached to the end of the beam. Figure 1 shows the crack patterns which developed in the specimen before the joint region was repaired. After each of the above tests, the fundamental natural frequency and viscous damping values were determined. These values are shown in Figures 2 and 3.

RESULTS AND CONCLUSIONS

The reinforced concrete specimen showed a significant drop in stiffness after the small energy transient loading, as indicated by the fundamental frequencies in Figure 2. The specimen had no cracks in it for the first set of frequency and damping determinations. From a practical viewpoint, the specimen with minor cracks is probably the best approximation of what exists in a real structure. The series of dynamic tests caused increasing numbers of cracks as shown in Figure 1. Associated with increased cracking are a decrease in fundamental frequency and an increase in damping as shown in Figures 2 and 3.

Tests of the repaired specimen showed that some of the stiffness was restored according to the natural frequencies shown in Figure 2. The joint repair restored the specimen to a level of performance similar to

---

[IV] McCafferty, R.M., "USBR Vibration Test System," Shock and Vibration Bulletin, The Shock and Vibration Center, Naval Research Laboratory, Washington, D.C., Bulletin 41, Part 3, December 1970, pp. 109-117 .

that originally observed after the small transient. There was little change observed in the frequency and damping values of the repaired specimen after it had been tested with the small and large transient loadings. The frequency changed from 11.9 Hz to 11.0 Hz and the percent of critical damping increased from 2.2 to 2.5. No new cracks developed in the beam or column during these tests and the mortar repair remained uncracked. However, during the shakedown test a brittle failure was observed within the epoxy mortar,.indicating less ductility in the repaired joint than in the original joint. The failure moment observed in the beam of the original specimen was 155 ft-kips, whereas the failure moment in the beam of the repaired specimen was 140 ft-kips. Even more significant was the difference in deflections which increased by a factor of approximately 14 in the repaired specimen for the shakedown test. The specimen performed poorly after cracks formed in the epoxy mortar. These cracks had the appearance of a brittle failure, occurred suddenly, and large pieces of material fell out of the joint during this final test. There was excellent bond between the concrete and mortar with most of the cracking occurring entirely in one material or the other. In a real structure where gravity loads are present in addition to the dynamic loads, the type of joint failure observed would probably have resulted in collapse of the structure.

In summary, this type of repair has the capability of restoring stiffness to the joint, but does not restore the ductility which is necessary for a structure designed to resist a major earthquake.

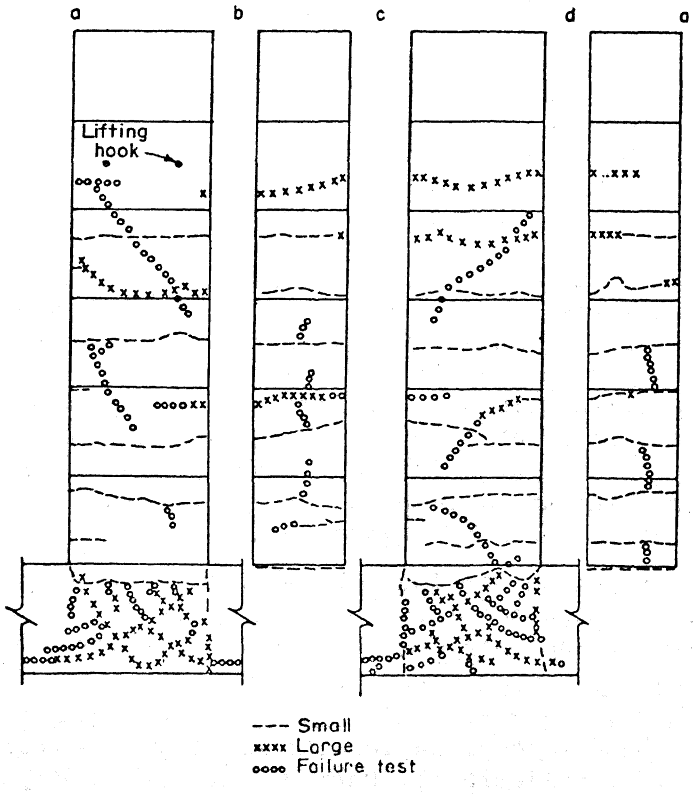

Figure 1 - Crack Patterns Before Repair

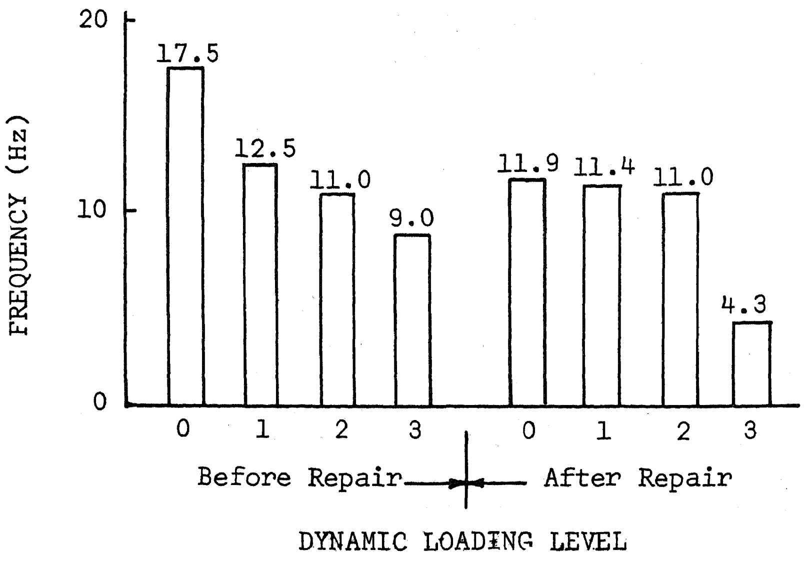

Figure 1 -- Frequency vs. Dynamic Loading Level;
(0) no load, (1) small transient,
(2) large transient, (3) failure

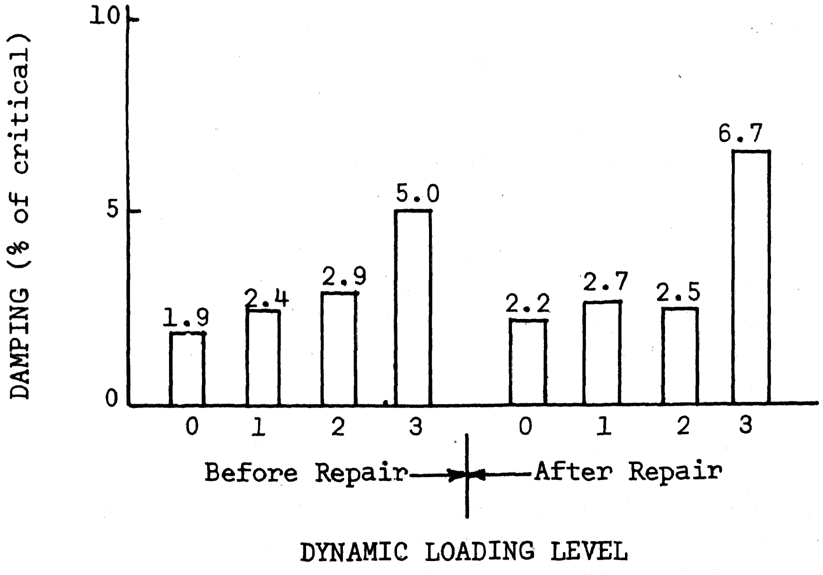

Figure 1 -- Damping vs. Dynamic Loading Level;
(0) no load, (1) small transient,
(2) large transient, (3) failure