I－B 271

OPTIMUM SHEAR REINFORCEMENT FOR RC PIERS OF BRIDGES SUBJECT TO DYNAMIC LOADING

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1. OBJECT OF THE STUDY

After Great Hanshin earthquake, it was realized that the RC piers of bridges suffered shear failure mechanism in addition to some local damages due to bad positioning of curtailment of main reinforcement in the tension side of the piers or discontinuity of concrete casting. Ductility of such structural elements depends greatly on main reinforcement, shear reinforcement and height of the pier relative to cross sectional dimensions. In this study, the optimal shear reinforcement percentages is focused using finite element method.

2. DIRECTION OF THE STUDY

Assume we have RC pier of dimensions and cross section as shown in Fig.1. The cross section is assumed to be square of constant dimension a=1.0m, height of the pier changes as 2.5, 5, and 7.5 m and main reinforcement ratio of 0.24, 0.64, and 1.0% . The top of the pier is assumed to be subject to constant vertical load of super structure of 1000 tf in addition to spectrum density function as dynamic loading. Spectrum analysis was carried out using finite element program called **MARC** for the mentioned piers with different shear reinforcement ratios as 0.0, 0.04, 0.1, 0.4, 0.6, 0.8 and 1.0%. Shear reinforcement ratio is defined as $\frac{As}{a.e}$ where; **As** is the cross sectional area of web reinforcement; **a** is the width of cross section; and **e** is the spacing of web reinforcement. For each case we could be able to obtain deformations, and response of acceleration, velocity and displacement. Also the stresses and strains were obtained. A comparison was carried out between studied piers leading to predicting of optimum shear reinforcement percentages for RC pier under dynamic loading. In finite element mesh, we used 3D element of 8 nodes for concrete and bar element of 2 nodes for both of web and longitudinal reinforcement. The required constitutive equations for modeling of steel and concrete were installed.

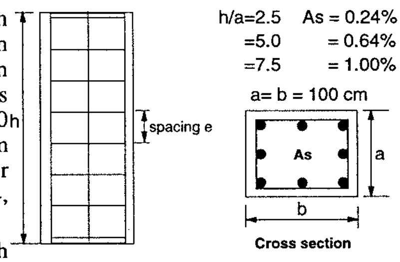

Fig.1 Dimensions of RC pier

3. RESULTS AND DISCUSSION

For each pier, we got the deformed shape. Comparing deformations of each pier, we found that as shear reinforcement increases, deformations decrease indicating improvement in the behavior of such piers. Fig. 2 illustrates deformed shapes for some of the analyzed piers. Fig.3(a and b) illustrates spectrum response at top of pier represented by acceleration, velocity, and horizontal displacement responses for the case of pier height (h) equals 5.0 m and main reinforcement percentage of 0.64%. As it is clear from the figure, as shear reinforcement increases, deformations decrease, however the rate of change is smaller between shear reinforcement percentages range from 0.5 to 0.7 % depending on main reinforcement and height of pier. For the same shear reinforcement, as main reinforcement increases, the effect of shear reinforcement decreases. Also for smaller pier heights, we found that the influence of shear reinforcement is higher and lower for bigger heights of the pier. This seems to be

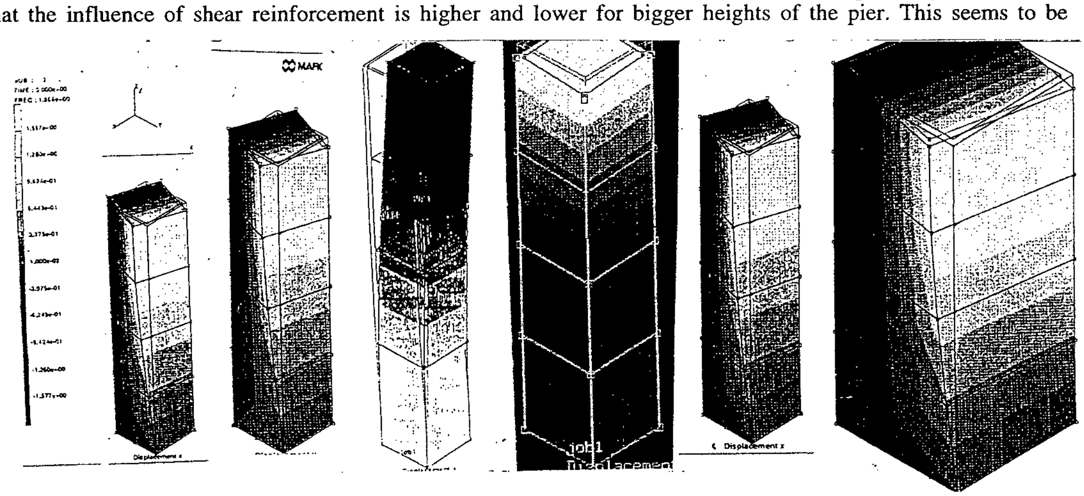

Fig. 2 Deformed Shapes of Some of Analyzed RC Piers

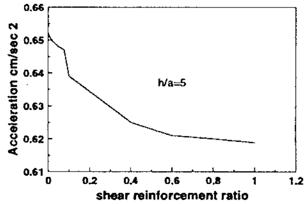

Fig (3a) Acceleration Response

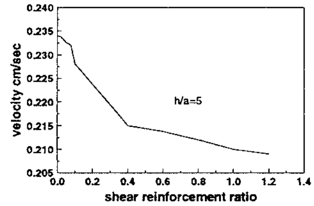

Fig (3b) Velocity Response

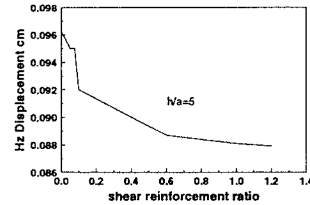

Fig.(3c) Displacement response

reasonable because for smaller pier heights, shear is dominant and hence the role of shear reinforcement becomes more effective. From this point, we concluded that for such RC piers, shear reinforcement percentage is recommended to be between 0.5 to 0.7 % depending on main reinforcement and height of the pier. Higher values should be corresponding to smaller main reinforcement ratios and smaller heights of pier and vice versa. Tables 1 shows response results for the two different pier heights of 2.5 and 7.5m respectively. Table 2 illustrates the effect of main reinforcement percentage on the results of response.

Table 1 Results of h/a=2.5 (h=2.5m, a=1.0m)

Descrption	h/a=2.5 (h=2.5m, a=1.0m)							h/a=7.5 (h=7.5m, a=1.0m)						
% As	0.0	0.04	0.2	0.4	0.6	0.7	0.8	0.0	0.04	0.1	0.2	0.4	0.6	0.8
Disp cm	.1478	.1474	.1466	.1463	.146	.1459	.15	.06	0.0599	0.0595	.0595	.0582	.058	.0579
Vel cm/s	.2325	.2324	.224	.21	.201	.197	.2	.0886	.08837	.0884	.0882	.0871	.0898	.089
ac cm/s^2	.4425	.4338	.42	.417	.416	.4156	.415	.1445	.14406	.144	.1436	.1417	.141	.1402

Table 2 Effect of Main Reinforcement percentage

Description	shear reinf.=0.04 %			Shear reinf. =0.1 %		
% Main rft	0.24	0.64	1.0	0.24	0.64	1.0
Displ. cm	.09746	.0958	.0724	.09748	0.092	.072403
Veloc cm/s	.2389	.2338	.14631	.23885	.232	.14627
accel cm/s2	.66613	.6479	.39653	.66542	.647	.39624

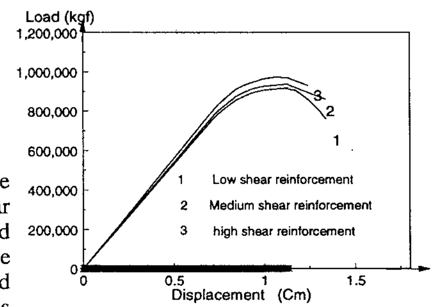

Fig.4 Load Deflection Curves

Fig.4 illustrates the load deflection curve for three piers having the same dimensions and main reinforcement ratios but different shear reinforcement percentages and subject to incremental vertical and horizontal static loading up to failure. From the curve, we can judge the role of shear reinforcement on the ultimate strength of piers and this role is more effective if smaller main reinforcement percentages are used.

4. CONCLUSIONS

From analysis of results of spectrum analysis, we could be able to predict the behavior of RC pier bridges under a certain type of dynamic loading. Some conclusions are summarized on the light of these results:

- Modal analysis is a way of predicting response of RC bridge piers in addition to the well known methods of evaluating ductility and ductility factor.
- To improve ductility of these structural elements, percentage of shear reinforcement should to be increased to be not less than 0.5% .Optimal ratio ranges from 0.5 to 0.7 % depending on height of pier and main reinforcement percentage. Higher ratios corresponding to smaller pier height and smaller main reinforcement.
- Much more study is still required to verify the dynamic behavior of such structural elements and to make clear the role of shear reinforcement on the ultimate strength of such structural elements. Also it is important to verify the influence of web reinforcement arrangement on the behavior.

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