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## Again, Shear Failure of RC Columns in 1995 Kobe Earthquake

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Minoru Yamada, born 1930, received Dr Eng. from Kyoto Univ. 1959. Prof. Kobe Univ., 1964 - 1992. He received Meritorious Paper Award from AIJ for his finding of shear explosion of RC short columns and its verification at Tokachi-Oki EQ 1968. He founded Disaster Mitigation Council in Hyogo-Pref, 1978 and given warning and advised urgent retrofiting of RC buildings in Kobe.

### Summary

Explosive cleavage shear failure of reinforced concrete short columns was found by the author in 1966 and reported at the 8. Congr. IABSE, New York, 1968 [1]. He had given his warning on the danger of collapse of buildings under earthquake and advised to retrofit existing buildings [2][3][4]. His warning were verified shortly after at the Tokachi-Oki EQ; Japan 16 May. In spite of his repeated warning to check and retrofit of old RC buildings and piers of high ways, designed before 1968, retrofitings were not carried out and at last many such old RC buildings with short columns were destroyed again at Kobe EQ. 1995 by shear explosion [5]. The author would like to give by this report his serious warning again on the urgent necessity of retrofiting of existing old RC buildings with short columns. This is the best way to mitigate the earthquake disasters.

### 1. Shear Explosion of RC Short Columns [1]

RC columns in rigid frames show three typical failure modes according to their shear span ratios ( $H/D$ ), i.e. shorter columns with smaller shear span ratio show shear explosion under predominant shear force  $V$ , medium length columns with medium shear span ratio show bending yield under predominant bending moment  $M$  and longer columns with longer shear span ratios show buckling under predominant axial load  $N$  such as shown in Fig.1, Photo 1 and 2. Critical value of shear span ratio ( $H/D$ )<sub>cr</sub> between shorter and medium length column i.e. shear explosion and bending yield is expressed as a function of axial load level ratio  $X=N/N_y$  and reinforcing index  $f_y p / f'_c$  [2][3][4] by :

$$\left(\frac{H}{D}\right)_{cr} = \frac{2[X + 2(1 + X)f_y p / f'_c](0.5 - d_1)}{7(1 - d_1)\sqrt{-0.10X^2 + 0.09X + 0.01}}$$

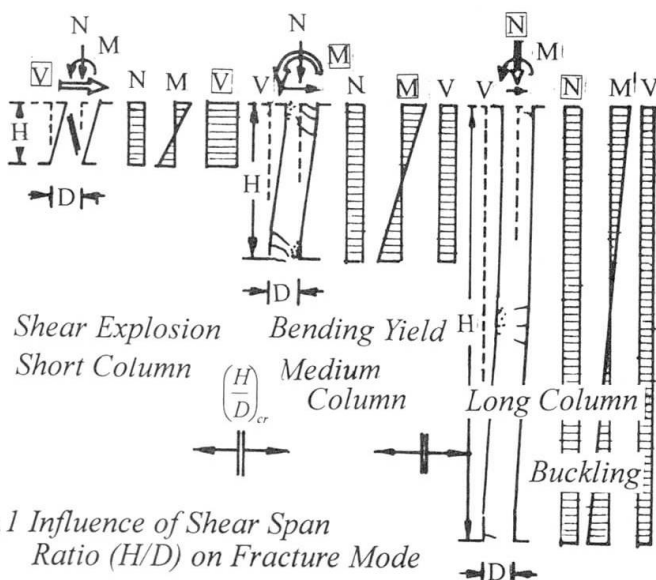


Fig.1 Influence of Shear Span Ratio ( $H/D$ ) on Fracture Mode

### 2. Earthquake Damages of Reinforced Concrete Buildings

Explosive cleavage shear failure of reinforced concrete short columns were verified shortly after the warning of author [1] by the collapse of many RC buildings at the Tokachi-Oki EQ Japan, 16 May. 1968 and reported at the 8. Congr., IABSE, New York, Sep. 1968 [1], and then at the Miyagiken-Oki EQ Japan, 12. Jun. 1978.



### 3. Urgent Necessity of Inspection and Retrofitting of RC Buildings

In spite of the warning of the author [2][3][4] on the existences of dangers of collapse by the explosive shear fracture of short columns in reinforced concrete, many buildings and piers of high ways were broken down again and again at the Loma Prieta EQ US. 17.Oct. 1987, the Northridge EQ US. 17. Jan. 1994 and at last the Kobe EQ Japan, 17. Jan. 1995. Such buildings and piers of high ways were designed and built according to the old structural design codes and standards with no consideration of the shear explosion of short columns.

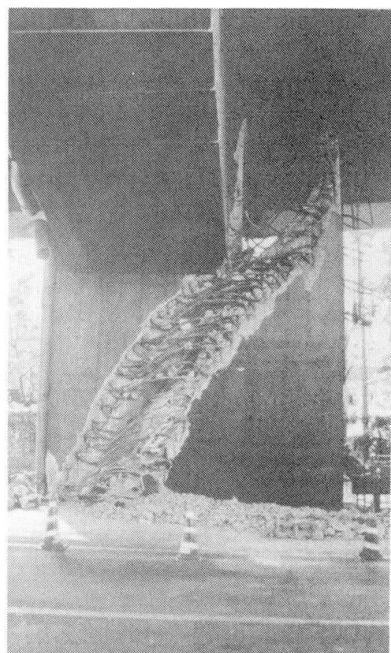


Photo 3 Highway Pier 1995 [5]

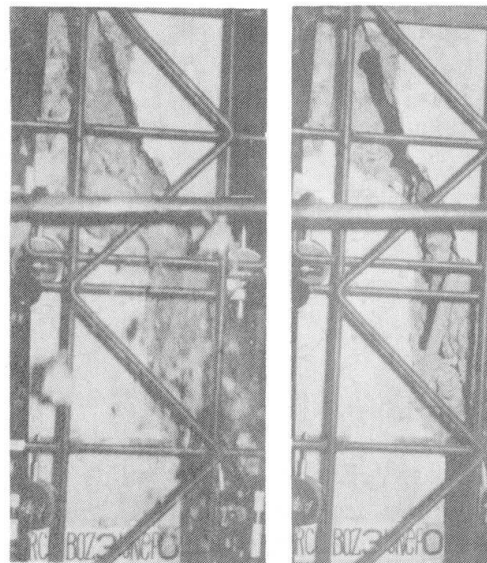


Photo 1 Shear Explosion [1]

### 4. Warning

There are yet very many old reinforced concrete buildings which were designed by old structural design codes and standards without consideration of shear explosion and far lower assumed seismic load than really excited load. These old buildings and piers of highways must be inspected and retrofitted as soon as possible. This is the most urgent and necessary way to mitigate the seismic disasters. The author would like to give his serious warning again on the necessity of retrofiting of existing old RC building with short columns.

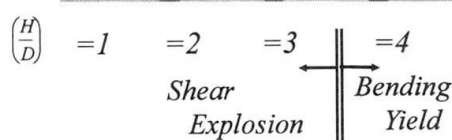
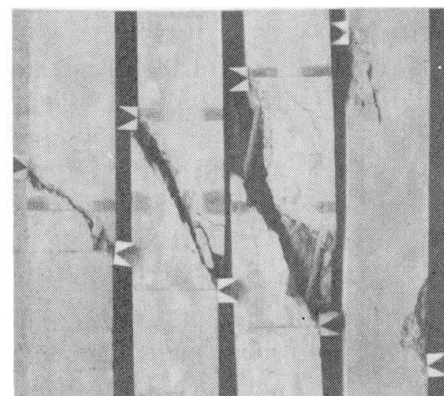


Photo 2 Influence of Shear Span Ratio(1968) [1]

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