# SHEAR FAILURE MECHANISM OF RC WALL-TYPE PIERS UNDER CYCLIC LOADS

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## 1. Objective

The objective of this study is to investigate shear failure mechanism of RC wall-type piers under cyclic loads and also evaluate JRA (Japan Road Association) design code recommendations on design of such members particularly whether or not they can be classified in deep beams category. If they are in deep beam category, mechanism of failure results higher shear capacity than conventional form of shear failure with large shear span to depth ratio which is also basis of JRA design code.

## 2. Experimental Investigation

Two RC walls have been tested in Public Works Research Institute[1] during the year 2004 in order to investigate shear behavior of such members under cyclic load condition. Existence and development of diagonal cracks have been measured by two displacement transducers installed where occurrence of the shear cracks have the highest possibilities. It is found that JRA design code dose not take into account extra shear capacity of RC wall-type piers if shear span (here is wall height) to depth ratio of the wall falls in deep beam category and produce more shear capacity. It is well explained by quite number of experimental investigations that for members with small shear span to depth ratio, conventional shear resistance mechanism yields very conservative prediction. Arch action which is formed in such members enhances shear capacity of the member significantly. Experiment results of this study also confirmed formation of different shear resistance mechanism similar to that observed in deep beams particularly.

Test specimens comprise of two RC walls with shear span (height) to depth ratio of 1.5, in deep beam category, under one and two directional cyclic loads respectively. Since specimens are wall-type member, longitudinal and lateral reinforcements are distributed all over the wall in order to produce a smooth distribution of stress over the member. Structural details of specimens and ultimate crack patterns are shown in Fig.1 and 2 respectively. Figure 3 illustrates envelope of cyclic responses of both specimens in positive direction. It is observed that in one-directional loading condition (No.1), bending cracks are developed in higher load than two-directional (No.2) load while shear cracks developed in almost same load level. This shows that shear crack might be independent to

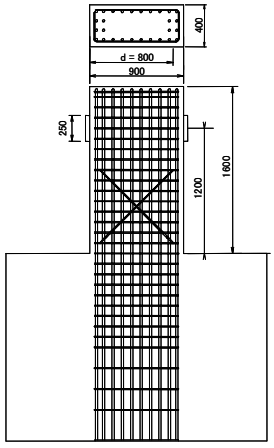



**Fig.1.** Detail of specimens

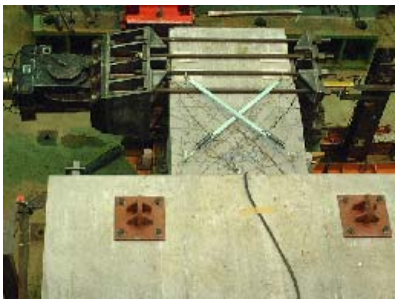
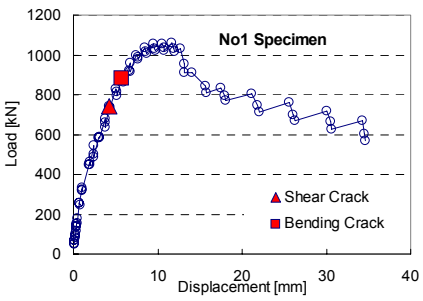


**Fig.2.** Ultimate cracks of specimen No.2



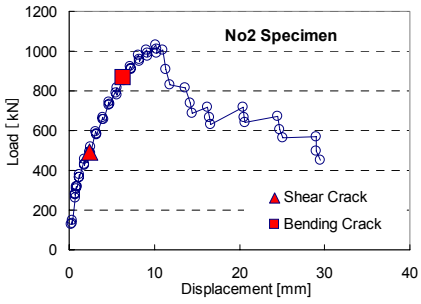




**Fig.3.** Envelope of cyclic response of specimens

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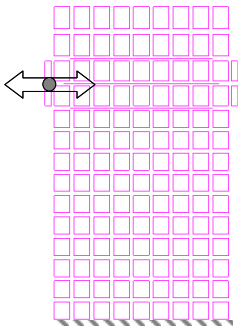
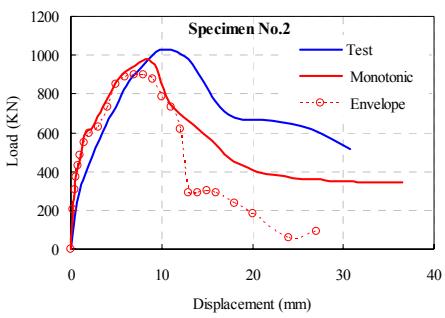


**Fig.4.** Ultimate cracks of specimen No.2



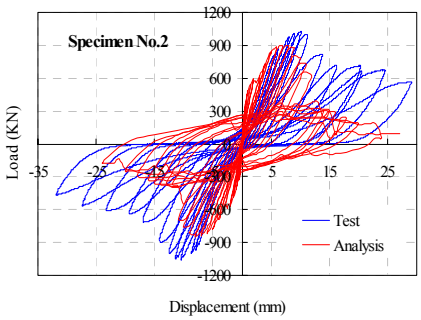




**Fig.5.** Monotonic and cyclic response of specimens No.2

loading pattern while is dependent to level of the applied load. Overall load capacity is not affected by loading pattern where in both specimens almost identical load capacity is obtained.

## 3. Analytical Investigation

Analytical study by means of nonlinear finite element method is also carried out subsequently. Finite element method applied for numerical modeling here is almost similar to one used for RC deep beam behavior investigation in previous study which is reported elsewhere[2]. Since failure mode is dominated by shear, analytical responses show sensitivity to the employed crack model as well as solution scheme where in numerical difficulties have been encountered. In order to study sensitivity of prediction to crack model, both rotating and fixed crack models have been applied. Fixed crack model, however, has a range of shear retention factor which is left to the user choice; consequently, depend on the applied retention factor $\beta_a$, results in a range of conservative, for smaller factor, and over estimated prediction for larger factor. On the other hand, rotating crack model results robust but conservative prediction in terms of load capacity of the member. Bond slide phenomenon is also taken into account for certain reinforcements. Other parameters have been considered in analyses are those of concrete confinement effect, concrete compressive strength reduction due to lateral cracks, steel hardening model, effect of foundation for full model simulation, interface elements between foundation and supporting pad as well as pre-stressing effect of anchoring bars which produce preliminary cracks before loading process. Concept of constant fracture energy of concrete is applied to the entire analysis of this study in order to eliminate mesh dependency in predicted response.

Results in this paper belong to only wall model (Fig.4) with rotating crack assumption and confinement effect. Figure 5 depicts the results of the wall under monotonic and cyclic load. As can be seen, the cyclic one is deteriorated significantly in terms of peak load and post peak response. Envelope of cyclic load is compared with monotonic load response and test results. In this figure, monotonic response has better agreement with experiment, though still under-estimated, but pre-peak and post-peak are in similar trend as experiment. In contrary, cyclic response shows not only smaller peak load but also a sudden decrease of load capacity just a few cycles after the peak. Fixed crack model is also examined and the results showed an increase in peak load and after the peak, load capacity was sustained to up to a certain deflection. It is found that, although rotating crack model can predict cyclic behavior of the member to some extend, but a mixed model with very low shear resistance in crack surface might improve the results. To this end the results can be used for further investigation of RC wall-type piers since the results are consistence, and also ensure a safety margin for structures with shear failure possibility.

## References

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2. Salamy M. R., Kobayashi H. and Unjoh S.; Experimental and analytical study on RC deep beams, *Asian Journal of Civil Engineering (AJCE)*, Vol.6, No.5, pp.409-422, November 2005.