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PASSIVECONTROLREINFORCEDCONCRETEFRAMEMECHANISMWITHHIGHS TRENGTHREINFORCEMENTSANDITSPOTENTIALBENEFITS AGAINSTEARTHQUAKES

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Abstract: Severe earthquakes continue to cause major catastrophes. Many devices in active, hybrid, andsemi-active structural control systems which are used as controllable force devices are costly to build andmaintain. The passive control reinforced concrete frame (PCRCF) reinforced with high strength steel only inthe columns presented here provides structural systems more resistance to lateral earthquake loadings atcomparatively lower cost. The effectiveness is demonstrated by a nonlinear static analysis using fiber modelfor a single story single bay frame. The study shows that the use of high performance steel in columns pre-vents formation of plastic hinges at the critical column base sections and failures are always initiated by re-inforcement yielding at the beam ends. Furthermore, after experiencing severe lateral drift, the passive con-trol design has small residual displacements compared to ordinary reinforced concrete frames. PCRCF re-habilitation and strengthening can be achieved more easily as compared with ordinary reinforced concreteframe.

Keywords:
earthquake;passivecontrol;highstrengthreinforcement;failuremechanism;residua ldisplacement

Introduction

In most reinforced concrete (RC) structures, a largestiffness is needed in order to limit structural deforma-tion for service load conditions. In seismic resistantstructures,however,theenergydissipationdemandsareimposedandinelasticdeformationsareperm ittedin special detailed regions of structures when the se-vereearthquake attacks.In particular,momentresistantframes designed according to the strong column/weakbeam concept are expected to undergo inelastic defor-mations by forming plastic hinges in the beams. Thecolumnsaresupposedtoremainelastictomaintainverticalloadcarryingcapacityandpreventpossiblecoll apse. Although the required flexural strength dif-ference between beams and columns at joint locationsenforces this ideal frame deformation mechanism, thedeformationsatthebaseofthefirststorycolumnsmustbeexcessivetoinitiatetheframetosway[1].Therefore, theformationofplastichingesatthebaseofthefirststorycolumnsisinevitableasshowninFig.
1. Although in some instances, the formation of plastichinges at the column bases may not be so critical re-garding the safety of the structure, these formation re- quires extensive rehabilitation efforts.
Moreover,the frame does not possess the recentering ability after un-dergoing severe lateral drift during strong shaking, andthe chances of complete demolition of the structure arealwaysthereincaseofexcessiveyielding at thecolumn base sections. Furthermore, the possibility ofexceeding the moment capacity at the top of the firstcolumns

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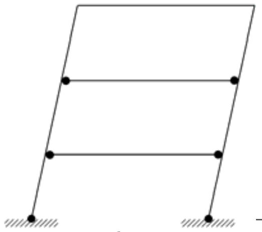


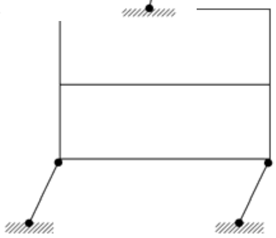


Fig.1Strongcolumn/weakbeamconfiguration

Fig.2Softfirststoryfailure

This paper is to describe the alleviation and preven-tion of the formation of plastic hinges in frame col-umns by introducing high strength steel reinforcementin RC frame columns, which is called here after as pas-sivecontrol RC frame (PCRCF).

1 MechanismofPCRCF

A conventional designed moment resistant frame usu-ally cannot successfully develop its ability against un-expected earthquake loadings due to limited flexuralstrength and the formation of plastic hinges at the baseof the first story columns. Excessive yielding at thecolumnbasesectionsmayleadtoeventualcollapse,and the soft first story failure mechanism is difficult toavoid. Moreover, even after the survival of structureagainst extreme lateral drift, the large residual defor-mations may suggest the need for complete demolition.By introducing high strength reinforcement in columns,PCRCF can safeguard its column base section fromexcessive yielding and can resultantly adjust structuralcharacteristics by using the reserve flexural strength atthecolumnbasesections.Furthermore,theyielding will only occur at beams ends. Due to elasticity of highstrength reinforcement in columns, recentering capacity can be improved with the reduced residual lateraldisplacement under extreme lateral loading. Therefore,repairscanbemadeeasier.

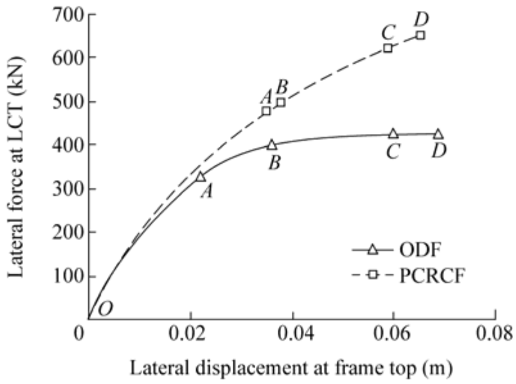
2 AnalysisModelsandMethod

To demonstrate the PCRCF mechanism and to investi-gatethebehaviordifferencebetweentheordinaryframeandthePCRCF,twosingle-storysingle-bayframes, ordinary frame (ODF), and PCRCF, were ana-lyzed.Thebehaviorsandfailuremechanismofboththe frames were estimated with nonlinear static analy-sis. Figure 4 presents the selected geometry and theloadingpattern for both theframes.

3 AnalysisofResults

Responsestages

Forcomparativestudy,boththeODFandPCRCFwereanalyzed and the results at each of the response stageswere described. The lateral load and displacement rela-tions are shown in Fig. 9 for the ODF and PCRCF. Thelateral load displacement relation of both the framescan be divided into four response stages. The end ofeach response stage is marked as *A*, *B*, *C*, and *D*. Thefourresponsestagesaredescribed asfollows.



FAILUREMECHANISM

From the observed fiber strains which are summarizedin Table 4, the extent of yielding at the four responsestagesatthecriticalsectionscaneasilybestudied.Moreover, the strains also provide guidance in the ex-act determination of the failure mechanism in each ofthe frame studied. From the available data in Table 4,Fig.10showsthelocationofplastichingesintheframesat the4 response stages studied.

Figure 10 and values of the fiber strains given in Ta-ble 4 show that at the response Stage 2, the failuremechanism developed in the ODF; however, PCRCFyielded only at BRE. Further even up to Stage 4,po-tential failure mechanism did not appear in the PCRCF.After the first significant yield at RCB, the ODF hasshown displacement ductility of smaller magnitude ascompared to the PCRCF. The lateral displacementval-uesgiveninTable 3showthatthe ODF at the endof response Stage 1 has 22.0 mm lateral displacementand at response Stage 2 ended was 36.0 mm, wherefailuremechanismdevelopedintheODF.However,thePCRCF laterally displaced to 35.0 mm at the end of re-sponseStage1anduntiltheendofthe

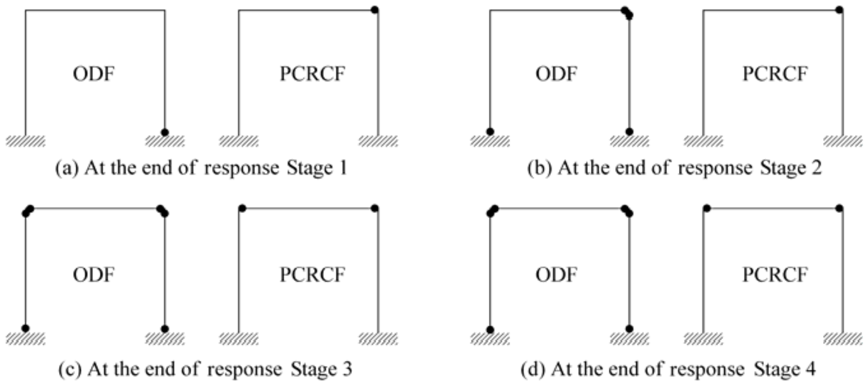


Fig.10LocationoftheplastichingesinODFandPCRCF

4 CONCLUSIONS

The passive control RC frame with high strength rein-forcementanditsexpectedbenefitsagainstearth-quakes has been compared with ordinary RC frames.Two single-bay single-story frames were selected andcompared.The followingconclusions canbedrawn.

(1) The PCRCF prevents the soft story failure andprovides more lateral load resistance capacity with lessreparable cost by simple replacement of ordinary con-ventional steel in the frame columns with high tensilestrengthsteel.

(2) The PCRCF shows signs of distress mainly at thebeam end sections which are potentially safe from thestability point of view of the entire frame as comparedwith the ODF where column base sections are badlyyielded.

(3) Compared to the ODF, the PCRCF rehabilitationand strengthening is easier because the repairs focus onbeam end sections instead of the more restricted col-umnbase sections.

(4) PCRCF reduces the residual displacement in theframesafter thelargelateraldisplacement.

(5) The PCRCF mechanism reduces the chances ofcomplete demolition by avoiding excessive yielding atcolumnbase sections.

The performance of PCRCF can be further improvedby providing concrete confinement at the beam endsand column base sections, since confinements at thebeam and column ends, as well as high strength steelreinforced columns, increase the ultimate deformationcapacity at the plastic hinges, and raise the deformationcapacityof the whole frame.Since the demonstration of the PCRCF mechanismhas been performed by using the single-story single-bay frame, the PCRCF response needs to be demon-strated for multi-story frames with dynamic loadings infuture studies. It may be helpful to mix some propor-tion of the high performance steel with ordinary one toachieve the response benefits. Hence, the optimum useof high performance steel in multi-story frame columnsalsoneeds tobeinvestigated.

References

[1] Paulay T, Priestley M J N. Seismic Design of ReinforcedConcrete and Masonry Buildings. New York: John WileyandSons, Inc., 1992: 98-106.

[2] Priestley M J N, Sritharan S S, Conley J R. Preliminary re-sultsandconclusionsfromPRESSSfive-storyprecastconcretetestbuilding.*PCIJournal*,1999,(11-12):42-67.

[3] El-Sheikh M T, Sause R, Pessiki S. Seismic behavior anddesign of unbonded post tensioned precast concrete frames.*PCIJournal*, 1999, (5-6): 54-71.

[4] Kurama Y, Pessiki S, Sause R. Seimic behavior and designof unbonded post tensioned precast concrete walls. *PCIJournal*,1999, (5-6): 72-89.

[5] Ricles J M, Sause R, Garlock M M. Post tensioned seismicresistant connections for steel frames. *ASCE Journal ofStructuralEngineering*,2001,**127**(2):113-121.

[6] Zatar W A, Mutsuyoshi H. Residual displacements of con-crete bridge piers subjected to near field earthquakes. *ACIStructuralJournal*,2002, **99**(6):740-749.

[7] KwanWP,BillingtonSL.Unbondedpost-tensionedbridgepiersI:Monotonicandcyclicanalyses.*ASCE,JournalofBridge Engineering*, 2003,**8**(2):92-101.

[8] Naaman S E, Jeong S M. Structural ductility of concretebeamsprestressedwithFRPtendons.In:ProceedingsoftheSecondInternationalRILEMSymposium,Non-Metallic Reinforcement for Concrete Structures. Belgium,1995: 379-386.

[9] Alsayed S H, Alhozaimy A M. Ductility of concrete beamsreinforced with FRP bars and steel fibers. *Journal of Com-positeMaterials*, 1999, **33**(19):1792-1806.

[10] Harris H G, Samboonsong W, Ko F K. New ductile FRPbars for concrete structures. *ASCE, Journal for CompositeConstruction*,1998, **2**(1): 28-37.

[11] Fischer G, Li V C. Intrinsic response control of momentresistingframesutilizingadvancedcompositematerialsandstructuralelements.*ACIStructural Journal*,2003,**100**(2): 166-176