RESEARCH DEVELOPMENT AND APPLICATION OF PRECAST SYSTEMS FOR BUILDING WITH CONNECTION USING UNBONDED POST-TENSION AND LOCAL DISSIPATER DEVICE

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Abstract

A precast connection concept, which has equivalent ability but more efficient compare to that of isolation concept was developed by Precast Seismic Structural System (PRESSS) in USA. This kind of connection usses unbonded post-tension system and replaceable dissipater device. The unbonded post-tension works to restore structural deformation back to its initial position after earthquake excitation, the dissipater device act like replaceable fuse when earthquake design load is exceeded. This concept was adopted to ACI 318 Code since 2002, NZS 3101:2006, and also in Indonesian Standard. The research, development, application of this concept were carried out in Indonesia in 2013 – 2014, using local materials and alternative precast system sustainable earthquake through service life of the building.

Keywords: *Earthquake-resistant sustainable building, capacity design concept, PRESSS, unbonded post-tension connection, replaceable dissipater device, local material and method.*

1. INTRODUCTION

In 2010, a new Indonesian earthquake map was published using new sesimic data, considering three-dimensional analysis and taking into consideration the effects of local faults. The return period of earthquake was adjusted comply to ASCE-10 (Irsyam and Sengara,2010). In line with this, Earthquake Building Code were also revised and issued by National Standard Bureau of Indonesia in 2012.

The new code follows new philosophy, which leads to a performance base design. This is due to public resistance to the classical capacity design concept. Major earthquake such as Loma Prieta (1989) and Northridge (1994) in California showed that buildings designed with capacity design concept behaved as expected. The death toll was small, but the damages interupted bussiness in the building since repairment took long time, high cost and difficult to carry out. The community protested the use of the capacity design concept and urged the engineers to find better design concept.

This paper discusses the concept of earthquake resistant building technology based on of precast method (PRESSS) as a "one stop solution" against new Earthquake Building Code. This paper covers the history and technology concept of PRESSS, and the research, development and implementation of the method in Indonesia.

2. THE HISTORY OF PRESSS TECHNOLOGY

PRESSS technology deals with precast concrete system, known as a system with intrinsic advantage in speed of construction, better quality and economic compared with conventional system. PRESSS Technology research in USA was initiated as respond to public preference that the building should experience insignificant damaged due to major earthquake so that the repairement is easy to carry out at low cost. This demand was responded well by precast concrete system.

PRESSS Technology research was led by Priestley in University of California at San Diego (UCSD). The research was carried out in eight years (1994 -2002) and funded by the National Science Foundation (NSF), Precast / Prestressed Concrete Institute (PCI), and Precast Concrete Manufacturer Association of California (PCMAC). The research work was concludes with a full-scale of five storey building at UCSD. The results were then adopted and cast in to the special section in the American Concrete Code, ACI T1.2-03 and New Zealand building code, NZS3101: 2006. The system was then applied to some various building in USA, Central America, South America, New Zealand and Japan.

Major earthquake in New Zealand occured in 2010 - 2011, due to a series of strong earthquakes caused by the movement of shallow faults (Bradley,2012). In those seismic events, buildings designed by PRESSS Technology experienced only minor damage.

3. PRESSS TECHNOLOGY CONCEPT

PRESSS technology is considered to be a revolutionary alternative technology that is able to produce high performance buildings (minimal damage due to major earthquake), and is easy to repair at low cost. The main feature of this method is the dry connection among components using unbonded post-tensioning system. The connection behaves like a spring that tends to restore the building to its original position (self-centering), when experiencing earthquake loads. In frame system, may be made continuously and beams are connected to the frame with unbonded post-tension system. Wall components are connected vertically. Rocking deformation is controlled to make the building perform well.

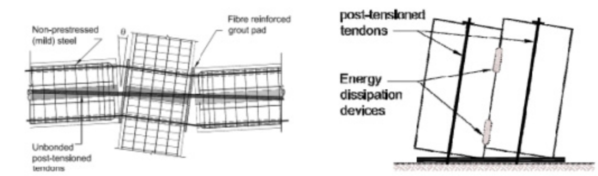
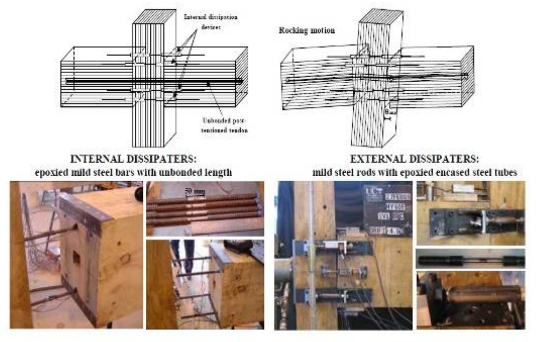


Fig. 1 Self centering with post-tension unbonded connection (Pampanin, 2010)

The concepts maybe combined with classical ductile concept using simple tool (made by local industry) as energy dissipater, This concept is known as hybrid concept. The dissipater tool can be installed internally as well as externally. The advantage of external dissipater is that could be replaced easily if damaged by major earthquake. To maintain keen architect look, the tool maybe hidden by simple techniques. The ratio of self centering to the ductile behavior will result in a hybrid histeresis spectrum known as flag shape. To obtain economical results, a ratio of combination of 60: 40 is recommended.



(a) Internal and external dissipaters and construction details.

Fig 2 Self centering+ductile(Pampanin,2012)

4. RESEARCH, DEVELOPMENT, AND IMPLEMENTATION IN INDONESIA

4.1 Difference Between Concepts of Classical Capacity Design and Post-tension Unbonded System

The difference between the performance of classical capacity design structure and PRESSS maybe observed from the test results of beam-column joint. Figure 3 should the hysteresis loops and joint damage pattern meeting requirements of special moment resisting frame (SMRF). The hysteresis loop is fat and the damage occurs in the beam

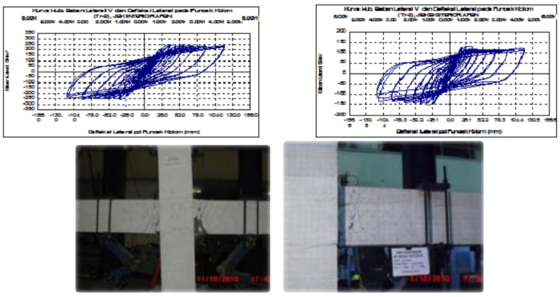


Fig.3 Hysteresis loop dan damage pattern of Precast SMRF (Yuwasdiki,2013)

Figure 4 shows hysteresis loop and deformation pattern of PRESSS beam column joint. Unbonded post-tension system provides self-centering effect, so that the structure behave elastically until a design earthquake load level. If the load exceeds the earthquake design load, this additional load is detainded by energy dissipation deviced, which physical form is analogous to the electrical fuse.

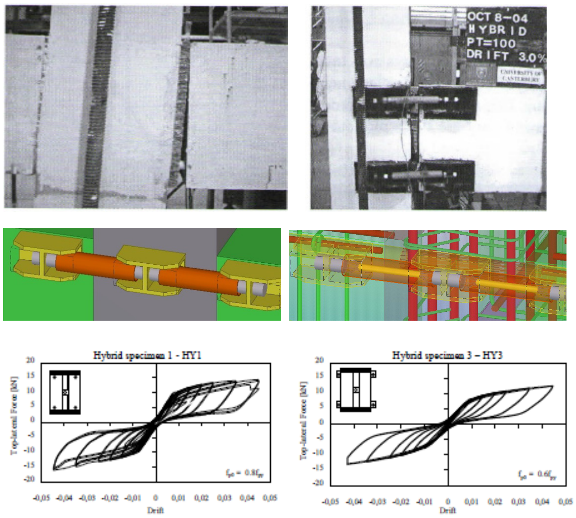


Fig. 4 Hysteresis loop dan damage pattern of PRESSS, (Pampanin,2010)

The configuration of dissipater device consists of the connection of steel bar using smaller bar confined within metal tube sheet. Exceeding load is directed to a smaller bar, having good ductility due to good confinement. This limits the stresses so that no overstrength occures, different to that occuring in classical capacity design. The hysteresis pattern flag shape is a combination of elastic linear post-tension unbonded and Bauschinger effect of steel bar.

4.2 Research and Development in Indonesia

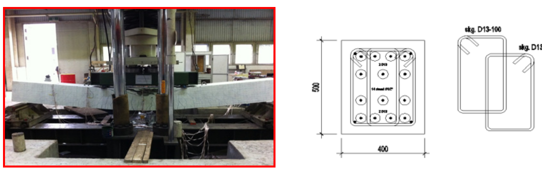
The aims of PRESSS research and development in Indonesia (Nurjaman,2013) are as follows :

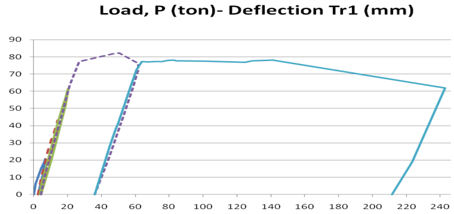
1. The confirmation of self-centering behavior of unbonded system post-tension system
2. The confirmation ductile behavior of hybrid system
3. Design and testing of local product dissipater device, confirmation test of beam column joint behavior, and
4. The testing of the connection of hollow core system to frame system.

4.2.1 Beam Testing

Gravity load testing was performed on four beam specimens in 2013 to meet the purpose of (1) and (2). The first speciment was the ordinary reinforced concrete beam, the second speciment was pure unbonded post-tension beam, the third speciment was hybrid concrete beam (50% post tension, 50% reinforcement), and the fourth one was segmental hybrid concrete beam.

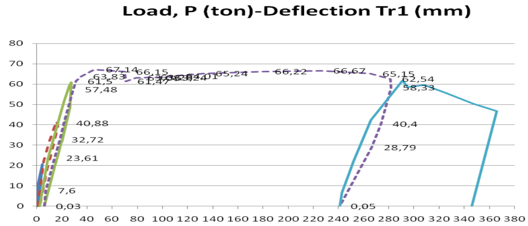
The documentation and test results are depicted in Figure 5. Self-centering system result in insignificant damaged, the crack load of pure post-tension beam was five times that of reinforced concrete beam. Crack load of hybrid beams was was 3.3 times compared to that of reinforced concrete beam. The ductility of the hybrid system (μ = 23) proved to be even greater than of reinforced concrete beam (μ = 17), so than be classified as Special Moment Resisting Frame (SMRF).





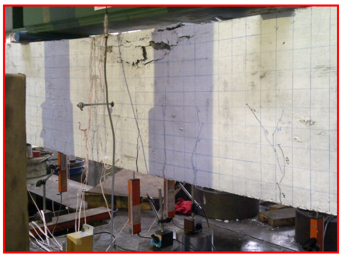
Moment	disp (mm)	P (ton)
crack	1.19	6.22
yield	14.19	41.5
max	50.59	82.31
ultimate	242.77	61.94
overstrength		2.01
P max/P yield		1.98
ductility		17.11

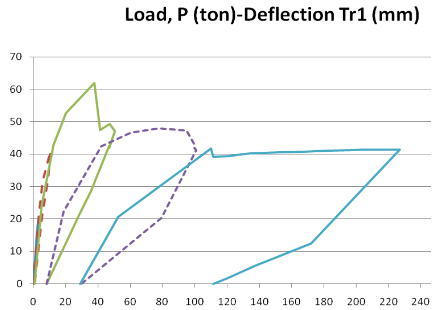
(a) Reinforced concrete beam



Moment	disp (mm)	P (ton)
crack	4.19	20.79
yield	15.59	41.88
max	226.37	66.67
ultimate	366.06	46.81
overstrength		1.64
P max/P yield		1.59
ductility		23.48

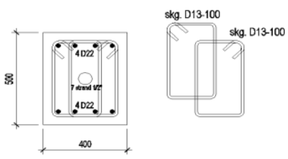
(c) Hybrid concrete beam

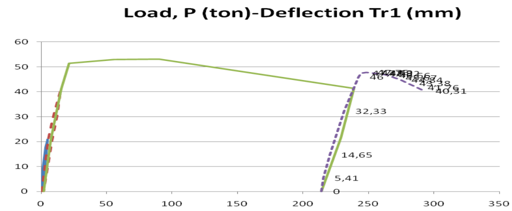


Moment	disp (mm)	P (ton)
crack	5.79	31.57
yield	20.29	52.67
max	37.39	62.03
ultimate	227.07	41.35
overstrength		1.51
P max/P yield		1.18
ductility		11.19

(b) Posttension unbonded concrete beam

Moment	disp (mm)	P (ton)
crack	3.59	17.76
yield	12.19	30.78
max	89.89	53.15
ultimate	292.67	40.31
overstrength		1.3
P max/P yield		1.73
ductility		24.01

(d) Segmental hybrid concrete beam

Fig. 5 Test result of beam speciments (Puslitbangkim,2014)

4.2.2 Dissipater Test

A local dissipater device was developed successfully in 2014, based on one of Indonesian method of connecting steel bars, with spiral reinforcement made from plain bar. This spiral is equivalent to metal sheet tube. The testing was carried out with the resulted prooved to meet requirements, as shown in Figure 6. Dissipater considered as beam reinforcement was also tested, and the result provided more as beam reinforcement also has be tested, and give more information about behavior of this beam. Further research will resume in the year 2014

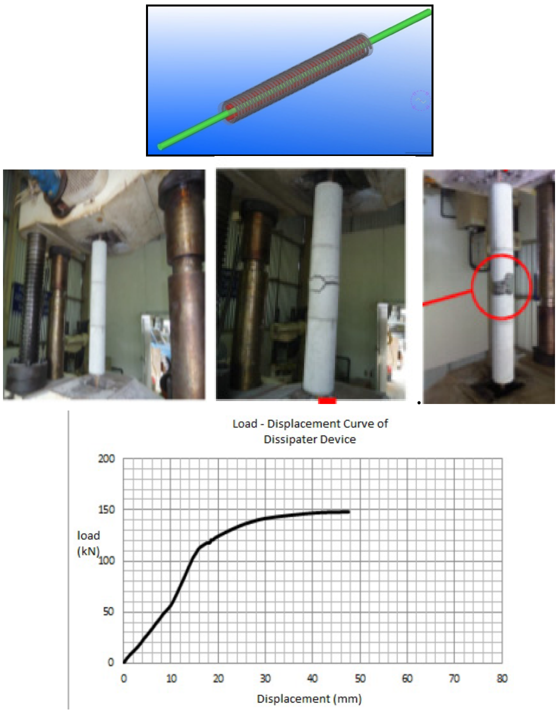


Fig. 6 Documentation dan test result of local dissipater speciments (Puslitbangkim 2014)

4.3 Implementation

Application of PRESSS to buildings in Indonesia, was first carried out in March 2014 at a temporary office building in Serpong as shown in Figure 7


Fig. 7 First building using PRESSS

5. CONCLUSION

PRESSS is an alternative technology to support the development in earthquake resistant building design. New earthquake code SNI 1726-2012 has been established to comply with the new philosophy, providing significant decrease in structural cost.

This technology is able to respond to public demand for designing high performance earthquake resistant building technologies, that experience only minor damage due to major earthquake. The damage is easy to repair in low cost.

Presently, an alliance of several precaster companies is conducting a two years research and development with local material and method (2013-1014), so that the technology may be applied in Indonesia for years ahead.

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