CYLINDRICAL WEDGE-TYPE COMPRESSION FREE BRACING SYSTEM FOR MOMENT RESISTING FRAME STRUCTURES

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ABSTRACT
In order to make the structure safe during seismic vibration, the structure can be strengthening by using different kinds of bracing system. If ordinary brace is used for this purpose, it will be buckled under lateral compressive load. This study will investigate the performance of the cylindrical wedge-type non-compressive bracing system. The whole experimental investigation has been done into two phases: in the first phase only uniaxial test has performed. In the second phase, the test has been performed by applying cyclic load through the hydraulic actuator on a half portal frame. The cylindrical wedge grip worked properly under compression by releasing the sacrificial steel, which prevent buckling of steel core. The hysteretic loops from tension load are not stable in size and slope even the same load. It is anticipated that non-linearity from the device itself or from the gripping device of the universal testing machine may cause this unstable hysteresis. The developed device needs some improvement to use in the inclined configuration. Pre-loaded spring as well as the improvement in steel casing for perfect alignment of both wedge and steel core might resolve problem from inclined configuration.

Keywords: Cylindrical; wedge-type; non-compressive; bracing system; buckling

INTRODUCTION
In the present world, building of high rise structures is a common trend not only in the developed country but also in the developing country. Tall buildings had changed the scenario of the landscape of the major cities in the world. The main problem of Tall structures is normally susceptibility to earthquake and wind. It is noticeable that the life safety purpose has been served in conventional structural configuration at the cost of property loss or repair. As the demand of the tall building is increasing day by day, some advanced technology should be implemented in the design methodology.

After Kobe earthquake a survey has been done on the damage of structural members and connections with respect to structural type. Damaged structures are classified as having resisting braced or unbraced frames. Di et al. (2009) mentioned that from the survey it had been confirmed that majority of damaged buildings had unbraced moment frames (MRF) as earthquake resistant system.

Tremblay (Tremblay, 2002) observed that under a severe earthquake, a nonlinear response generally initiated when the compressive force in one of the braces reached to its ultimate value and buckling of that brace occurred. In other words, the main problem that is faced by conventional bracing is the buckling during compression. However, the members that act only in tension and moves freely in compression also decrease the effectiveness of the system. It is because until it reaches the start of the compressive point there is not that much buckling compressive strength. For this reason, Golafshani et al. (2006) suggested the development of such type of bracing mechanism that could endure tensile force every time with a resisting stiffness against earthquake excitation.

In this study, therefore the main focus will be not only on the mitigation of the problem associated with conventional bracing system but also on the behavior of tension only bracing member.

METHODOLOGY

The method of doing test of this research work has been influenced by the technique of prestressing at which a small chuck plays main part to achieve goal. The strand chuck is also known as wedges, grippers and lock off.

PREPARATION OF THE TEST ASSEMBLAGES FOR THE TEST

Cylindrical wedge-type non-compressive device

The Cylindrical wedge-type non-compressive device has three parts (i) Conical shaped Grip (ii) Outer cylinder (iii) Cover of the cylinder.

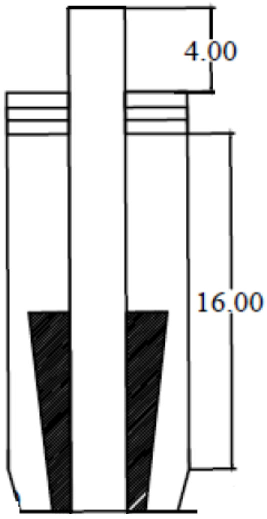


Fig. 1: (a) Outer cylinder (b) Cross sectional view of Cylinder with wedge grip (All dimensions are in cm)

Sacrificial Bar

For the UTM test**,** a 12mm diameter rod reduced to 9mm diameter in the yielding part has been used. Total six numbers of specimens are with this dimension. For the top part 27mm diameter bar with 12mm groove of 6cm length has been used as an adapter. From the top edge of 12mm bar 6cm length is threaded to screw inside the adapter rod.

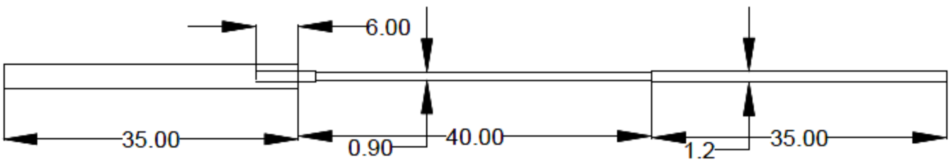


Fig. 2: Schematic diagram of specimen for uniaxial test(All Dimensions are in cm)

Loading protocol for testing

Since no specified loading protocol has been depicted in the past research for non-compressive bracing system, loading provision for BRB in Fema-450 has been chosen to do the final test.

Instrumentation

For the instrumentation purpose, load cell of capacity 50 ton, LVDT and strain gages were installed to measure force, the linear displacement and strain respectively. Strain gages are put at 5cm, 20cm and 35 cm from the bottom portion of yielding part. According to this placement, the strain gauges will be introduced in this report as top, middle and bottom strain gauge respectively. Finally all the instruments were connected to the data logger to record the respective data.

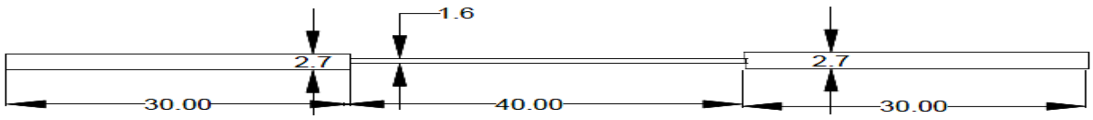
Testing

After completing all the arrangement shown in figure 3, displacement control test has done following the loading protocol. Total six specimens have been tested by universal testing machine. This whole process has been controlled from the observing data of data logger. Among six, three specimens have been tested till rupture.

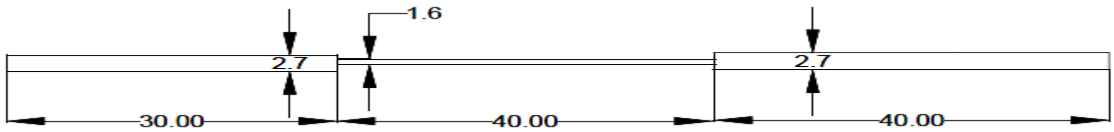
Fig. 3: Test set up for uniaxial testing at Structural Engineering laboratory at AIT

Brace for actuator test

For the actuator test, 27 mm diameter rod reduced to 16mm diameter in yielding part has been used as bracing. Two piece of specimen are connected with a coupler. Only one specimen has been subjected to the test with hydraulic actuator.



(a)



(b)

Fig. 4: Specimen for test with actuator (a) upper part (b) lower part (All Dimensions are in cm)

Coupler

To avoid the yielding in the coupler, the area of the coupler kept higher than the expected yielding zone of 16mm diameter portion. The thickness of the coupler is 12mm and outer diameter is 51mm. Total length of coupler is 10cm.

Steel plate

For the test with actuator, two steel plates are used. Between these two plates, one is used as gusset plate and another one is used as connector with the hinge support. Both plates are 10mm thick.

(a)

(b)

(c)

Fig. 5: (a) 12mm thick coupler (b) Gusset plate (c) Steel plate for using at the lower portion of bracing

Set up of Test Assemblages for second phase of final test

The specimen has been subjected to quasi-static cyclic loading. Lateral load was applied at two (2) meter height from the center of the hinge pin by a hydraulic actuator with capacity of 30ton. All components in the frame are consisted with W250x76.0 kg/m. The frame is supported by a hinge. The brace has been connected to the gusset plate with help of two steel plates (figure 3). Both the steel plates were bolted in such a way that the outer cylinder of the energy dissipating device can be fit well in between. A clearance length of cm 15% of the yielding length of brace has been kept between the gusset plate and brace to restrain the brace from hitting the gusset plate. The another end of the brace has been welded with a steel plate of thickness 10mm and thus the plate has been connected to another hinge support.

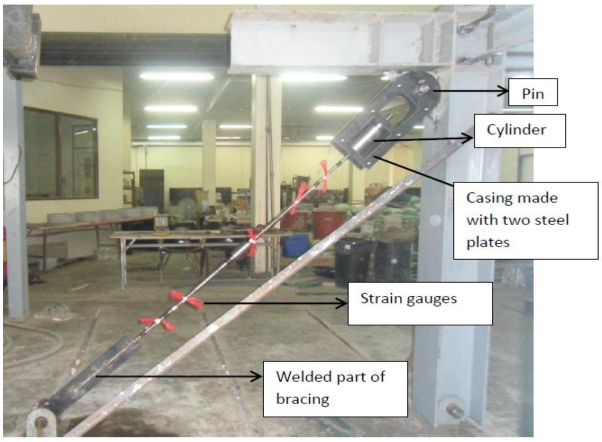


Fig. 6: Set up of brace with frame at Structural Engineering laboratory at AIT

Instrumentations

Instruments were installed in order to measure the force, the displacement and the strain occurred during testing. LVDT has been placed at the tip of steel beam. Strain gages are placed at five positions. From the edge of top yielding part strain gages are provided at 5cm, 20 cm, and 36 cm distances. From the bottom edge of yielding part at 5cm and at 20 cm distance strain gages are provided.

Test

After completion of the erection of the test assemblages the alignment has been checked. Then, the displacement transducers and the strain gages were connected to the data logger. Respective Coefficients of each LVDT, strain gage and load cell were adjusted to the data logger. All channels of the strain gages were checked to ensure that data were recorded to the data logger. Before starting the test, a zero reading was taken for all devices, except data from the actuator load cell.The lateral load implemented by the actuator to all assemblages according to the predetermined story drift. Steps of the movement in each story drift were divided into four steps. A movement to a peak backward position is termed as step one. At this time test assemblage was pushed by the actuator. In the same manner, step three was a movement to a peak forward position. In this case the, assemblage was pulled by the actuator. At Step two and four the assemblage returned to the initial position.

RESULTS AND DISCUSSIONS

Discussion on results got from the test with Universal Testing Machine (UTM)

Hysteretic Behavior

The behavior of the steel specimen under both tensile loading and cyclic axial loading perceived from the test can be explained from the force-displacement response diagram (figure7a). The steel core did not exhibit general hysteretic behavior. For example, the hysteretic loops from tension load observed in the experiment are not stable in size and slope even the load are same. It is anticipated that non-linearity from the device itself or from the gripping device of the universal testing machine may cause this unstable hysteresis. Moreover, the specimen did not subject to any degradation of stiffness because of lateral deformation due to compression with the increment of displacement amplitude. In this research work, the slope of the hysteresis curve just after compression depended on the locking efficiency of both developed and existing UTM's lower grip.

Stress-Strain relationship

The entire specimens showed linear behavior with in the elastic range and after yielding there were some non-linearity in behavior of steel which was obvious. From the stress-strain diagrams (figure 7b) it is reflected the fact that during compression the grip unlocked properly as there was no negative strain values except the Poisson's strain values at the very beginning. The stress-strain diagram of the specimens underwent cyclic axial loading, did not show any compressive strain. It exposed the fact that the specimen did not suffer through any local buckling or fracture because of non-compressive device.

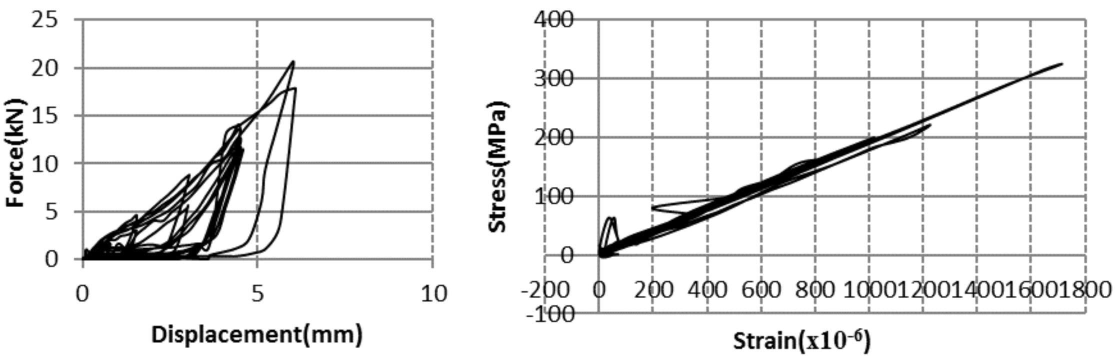


Fig. 7: (a) Force-displacement response of specimen (b) Stress-strain diagram of specimen

Discussion on results got from the test with hydraulic actuator:

Final test has been performed by hydraulic actuator of capacity 30ton.After completing first step (6 cycles) of FEMA loading protocol it has been noticed that the recorded data of loading was very smaller than expectation as the developed grip did not hold the brace in tension.

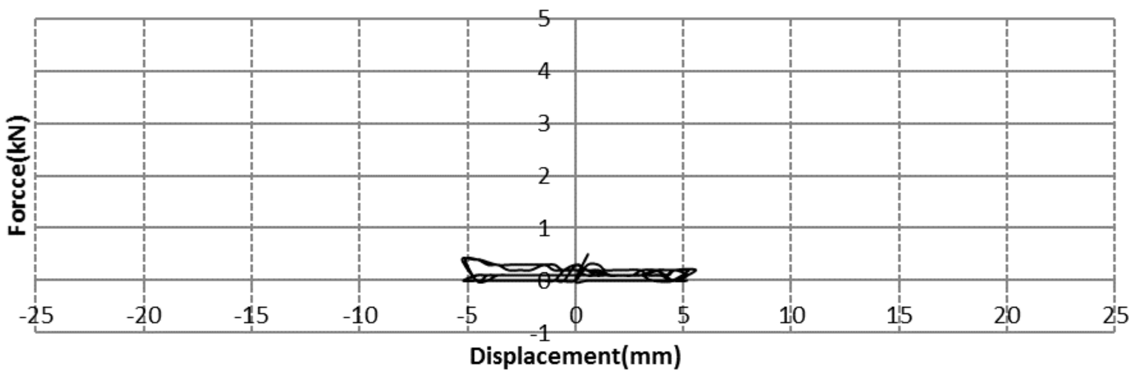


Fig. 8: Force - displacement response for 6 cycles of 5.3mm displacement

CONCLUSIONS

The integrated intent of this research work is to develop a non-compressive device to disengage compression from bracing system. To verify the performance of the developed wedge-type grip, the entire experimental process has been divided into different phases. On the basis of the experimental results, the following conclusions can be drawn:

1. The cylindrical-wedge type compression free hysteretic energy dissipative device was experimented through various loading protocol and exhibit steel hysteretic behavior over steel plasticity under tension load. The device worked properly under compression by releasing the core plate (sacrificial steel), which prevent buckling of steel core.

2. The hysteretic loops from tension load observed in the experiment are not stable in size and slope even the load are same. It is anticipated that non-linearity from the device itself or from the gripping device of the universal testing machine may cause this unstable hysteresis.

3. The device, developed in this research, cannot be used in the inclined configuration since the orientation of wedges is affected by gravity. Pre-loaded spring to keep the wedge in place might help resolve the problem. Furthermore, the steel casing which keeps the core steel in proper alignment might resolve problem from inclined configuration.

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