UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

"Assessment of material strain limits for defining different forms of plastic hinge region in concrete structures"

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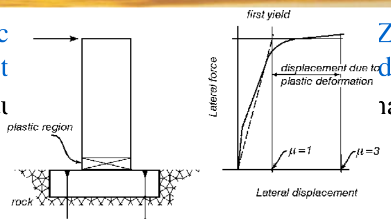
Outline

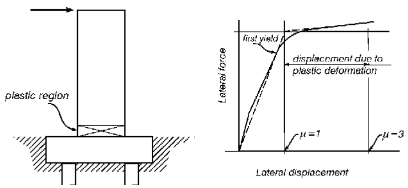
1. Background
2. Objectives
3. Experiment Details
4. Test Results and Observations
5. Calculation of Curvatures
6. Revised Limits

Background

- Until the rec ... ZS3101, the level of detailing det ... ductility
- Structural du ... ation in individual hinges



(a) Structural wall with stiff foundation



(b) Structural wall with flexible foundation

Background

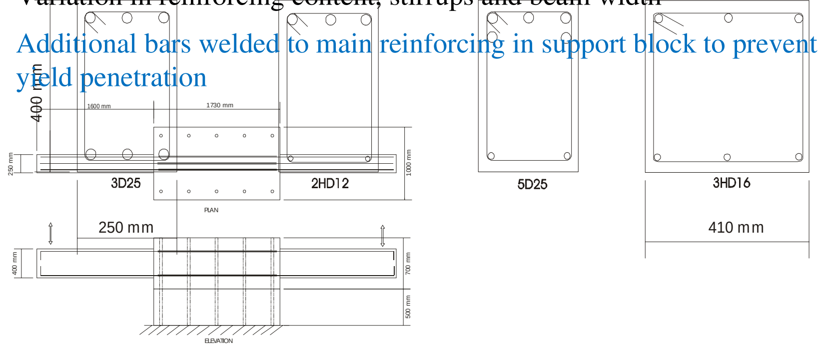
- Consequently, the revised loadings standard (NZS 1170.5:2004) requires the detailing of plastic hinges to be based on inelastic deformation demand of the hinges
- The revised concrete standard (NZS 3101:2006) classifies hinge regions based on material strains, in the form of curvatures or shear deformation.
- Plastic regions divided into three categories:
  - Nominally ductile (NDPR)
  - Limited ductile (LDPR)
  - Ductile (DPR).

Objectives

- When 2006 code released, only limited experimental results were available
- Database improved by Fenwick and Dhakal with recommendations on limited ductile and ductile members
- Still significant gap in tests meeting nominally ductile detailing requirements
- Experimental program to fill this gap
- Revision of existing limits for ductile and limited ductile hinges

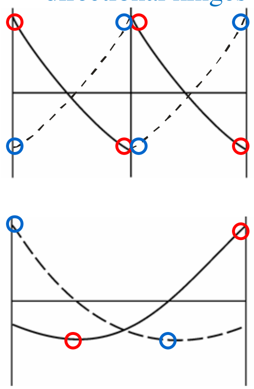
Experimental Details

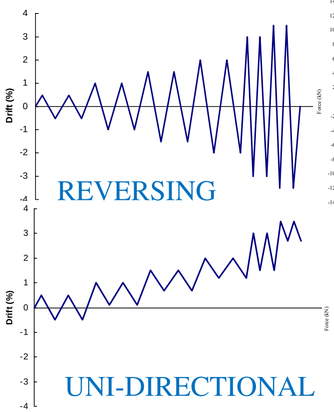
- Tests conducted on eight cantilever NOMINALLY DUCTILE beams
- Variation in reinforcing content, stirrups and beam width
- Additional bars welded to main reinforcing in support block to prevent yield penetration

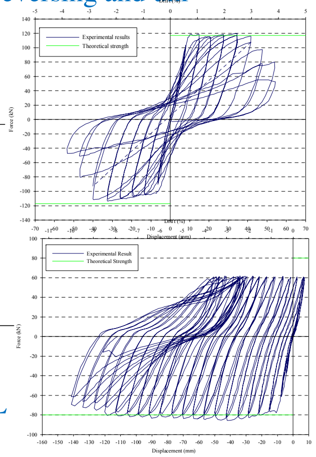


Experimental Details

- Two different loading protocols used to form reversing and uni-directional hinges

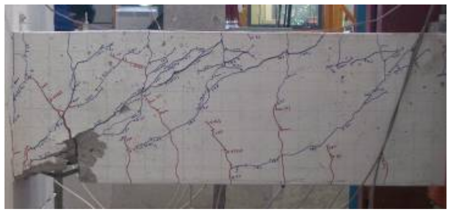




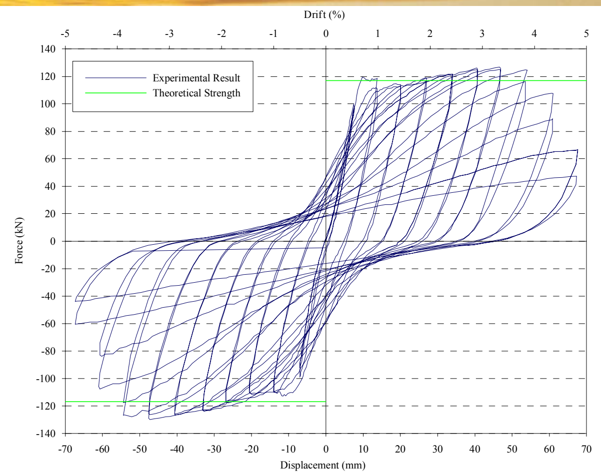


General Observations

- Yield of reinforcing occurred on way to 1% drift except tests B1 and B2 due to crushing of concrete
- All beams formed diagonal tension cracks
- Failure due to bar buckling and leading to fracture

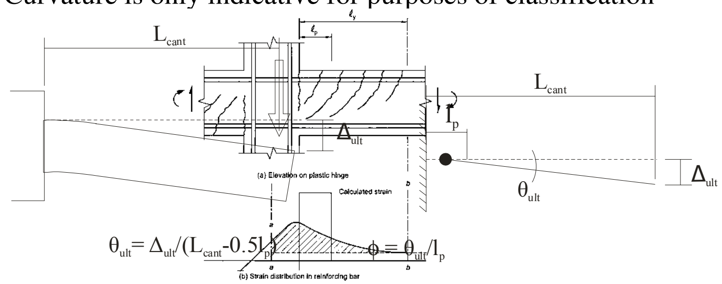


Typical load-displacement response

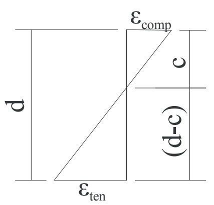


Calculation of ultimate curvature

- Curvature is calculated as rotation from deflection profile divided by effective hinge length as defined in NZS3101
- Assumes uniform curvature over effective hinge length
- Curvature is only indicative for purposes of classification



Calculation of curvature limit



$\varphi_{comp} = \varepsilon_{comp}/c$ $\qquad \varepsilon_{comp} = 0.004$

$\varphi_{ten} = \varepsilon_{ten}/(d-c)$ $\qquad \varepsilon_{ten} = 0.015$

Nominally ductile

$$\gamma = \frac{\varepsilon_y}{d - c} \Longrightarrow \varphi_y = \frac{2\varepsilon_y}{h}$$

Ductile and Limited ductile

Design limits vs Experiment

	Experiment	Ratio ultimate/design	
Test	φ_u (mm^{-1})	$\varphi_u/\varphi_{all,c}$	$\varphi_u/\varphi_{all,s}$
A1	0.000161	3.75	4.70
A2	0.000215	5.01	6.27
B1*	0.000108	5.24	2.47
B2*+	0.000242	7.33	3.46
C1	0.000134	8.47	2.57
C2+	0.000296	11.7	3.55
D1	0.000188	3.15	5.79
D2+	0.000538	5.64	10.4

Curvature ductility for different plastic hinges

	Beams		Columns		Walls		
	Nominally ductile	Ductile	Limited ductile	Ductile	Nominally Ductile	Limited Ductile	Ductile Doubly Reinforced
Average	13.3	24.8	19.5	29.2	7.5	9.2	20.8
Std. deviation	5.2	6.9	4.6	5.6	3.6	2.2	3.8
Lower Characteristic	4.7	13.5	11.9_y	20.0	1.6	5.6	14.6
Number of units	6	25	7	9	5	17	8

Design Recommendations

Beams			Columns		Walls		
Nominally Ductile	Limited Ductile	Ductile	Nominally & Limited Ductile	Ductile	Nominally ductile	Limited ductile*	Ductile**
4.5	9	13.5	12	20	1.5	5.5	14.5

Conclusions

- Experimental tests were conducted on nominally ductile beams to provide data to set design material strain limits for this category
- Experimental results on ductile and limited ductile plastic hinges from literature were used to update the design curvature ductility for these two categories.
- An approximate method is recommended to estimate yield curvature, which does not require to determine the NA depth.
- Updated design limits have been proposed for nominally ductile plastic regions in terms of curvature ductility

Acknowledgements

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