



Backbone model for performance-based seismic design of RC walls for low-rise housing

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- The number of new economic housing units in Mexico has increased considerably
- These units are one-to-two stories high and have been constructed with RC walls
- $t_w = 100 \text{ mm}$, $f_c' \sim 15 \text{ MPa}$, $\rho \leq \rho_{\min}$ and welded-wire meshes. Also, $\sigma_v \sim 0.03 f_c'$.

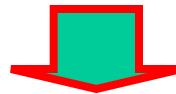


Speed of construction and economy !



Specific wall characteristics: existing analytical models and requirements in current codes are not directly applicable:

- Models have been developed considering a wide range of the parameters that control de behavior
- Walls with web shear reinforcement made of welded-wire meshes are not typically included
- Models have been calibrated on the basis of results from quasi-static tests only
- Some of them have been developed for academic purposes.



To develop a PB backbone model capable of predicting the seismic behavior of RC walls for low-rise housing

Experimental program

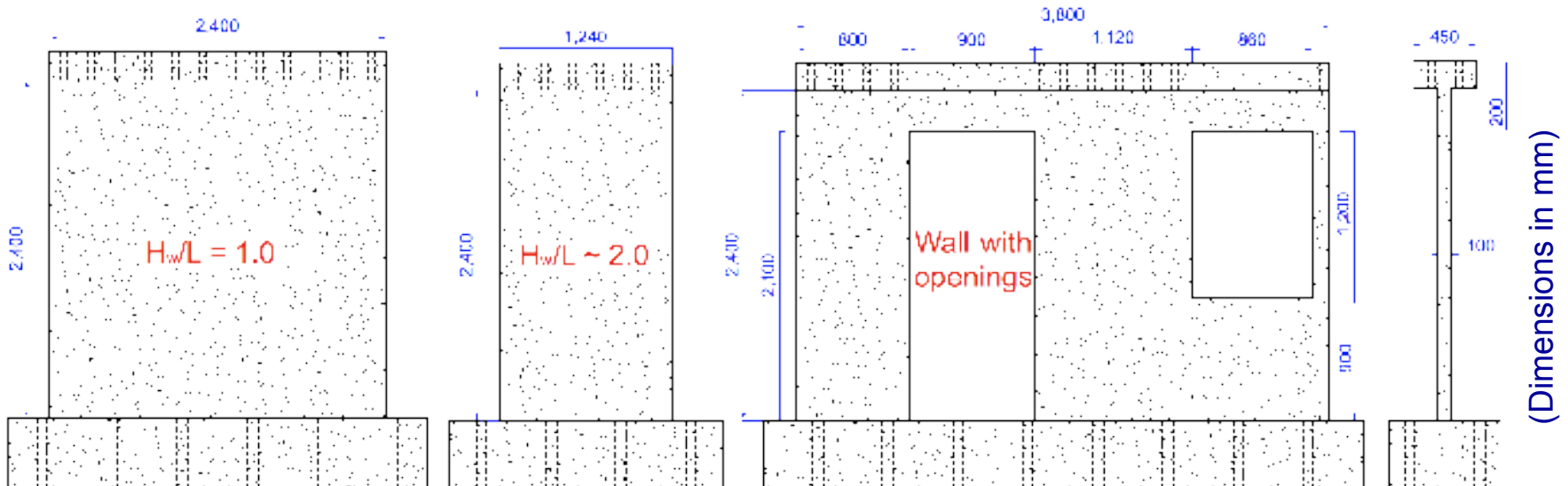
39 isolated walls:

Variables studied:

“Current design and construction practice”

Height-to-length ratio:	0.5, 1.0, 2.0 and wall with openings; $t_w=100$ mm
Type of concrete:	Normalweight, cellular and self- consolidating
Web steel ratio (ρ):	$100\% \rho_{min}$ (0.25%), $50\% \rho_{min}$ and 0%
Type of web reinforcement:	Deformed bars and welded small-wire meshes
Type of testing:	Dynamic and quasi-static

Typical geometry



Experimental program

Test setups:

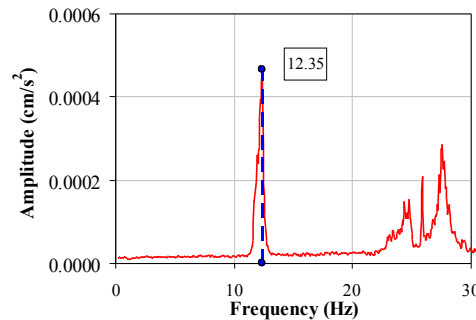
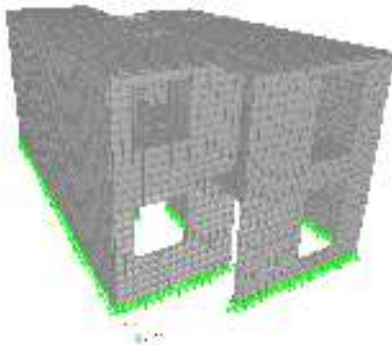


Dynamic testing



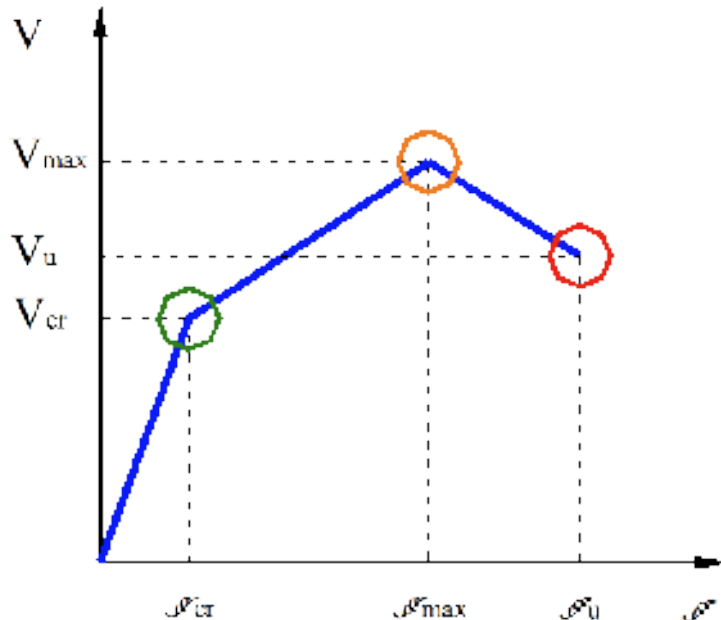
Quasi-static testing

Analytical models



Ambient vibration

Performance levels and model development:



Diagonal cracking (V_{cr}, Δ_{cr})

Strength (V_{max}, Δ_{max})

Ultimate deformation capacity (V_u, Δ_u)

For setting the functional form:

- Existing models
- Results of previous studies
- Test observations
- Fundamentals of RC behavior
- Recommendations: ACI-318 and NTC-C

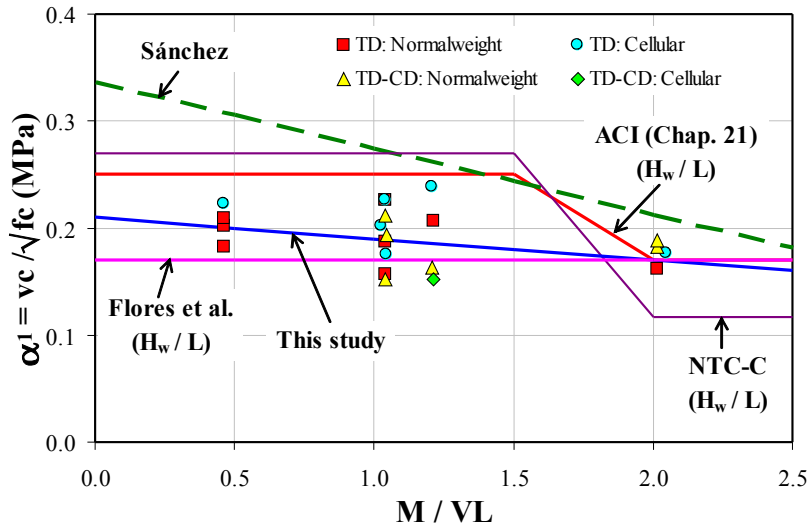
Improved by:

- Iterative regression analysis
- Investigation of trends between residuals and design variables

Model equations

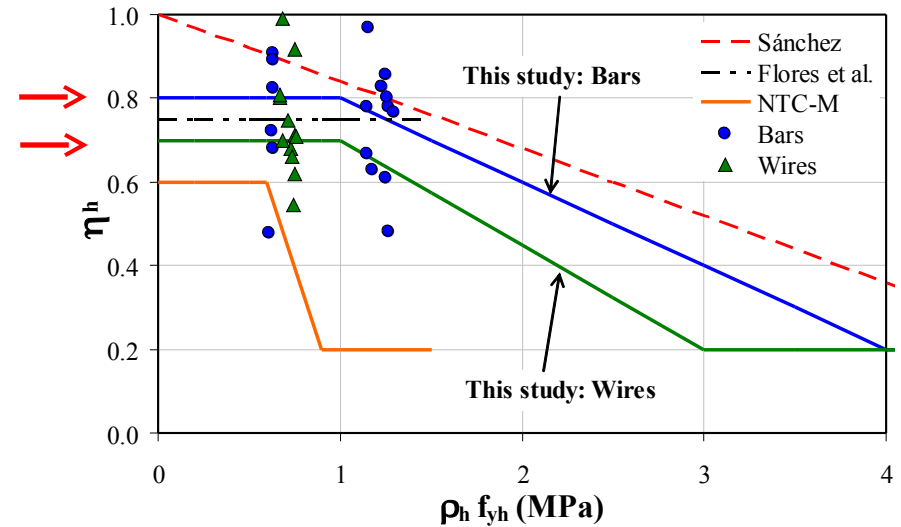
Shear strength capacity:

$$V_{\max} = V_c + V_s = [\alpha_1 \sqrt{f_c'} + \eta_h \rho_h f_{yh}] A_w \leq \alpha_2 \sqrt{f_c'} A_w \rightarrow \text{Maximum}$$

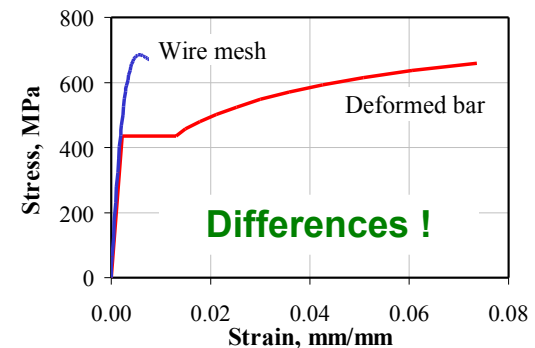


Relative contribution of concrete to wall shear strength

- Geometry and boundary conditions (M/VL)
- Vertical axial stress (σ_v)
- Vertical web steel ratio (ρ_v)

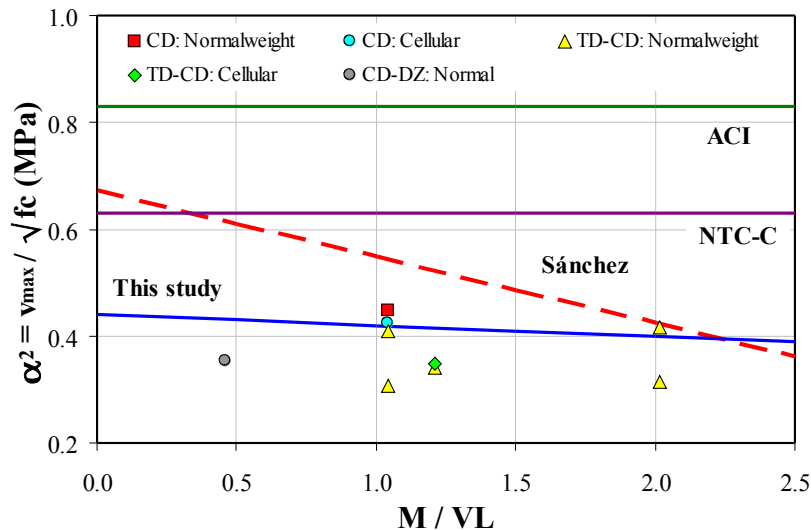


Efficiency of horizontal web steel ratio (ρ_h)



Shear strength capacity:

$$V_{\max} = V_c + V_s = [\alpha_1 \sqrt{f_c'} + \eta_h \rho_h f_{yh}] A_w \leq \underline{\alpha_2} \sqrt{f_c'} A_w \longrightarrow \text{Maximum}$$



Relative contribution of concrete to wall diagonal compression shear strength

Why the differences?

f_c and ρ_{h-v} higher than those used in this experimental program.

$$V_{cr} = V_c = \alpha_1 \sqrt{f_c'} A_w \longrightarrow \text{Diagonal cracking}$$

$$V_u = 0.8 V_{\max} \longrightarrow \text{Ultimate}$$

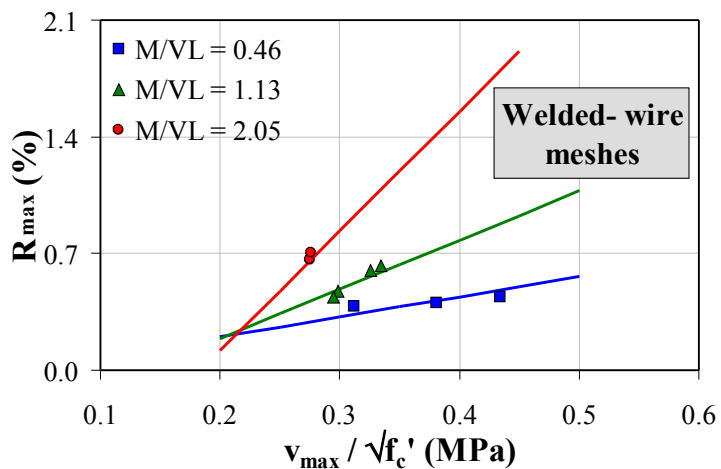
Model equations

Displacement capacity: (in terms of drift ratio)

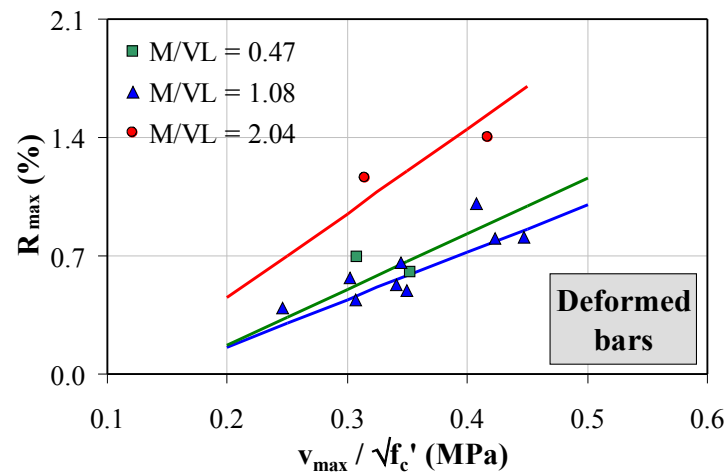
$$R_{cr} (\%) = \left(\frac{V_{cr}}{K_{cr}} \right) \frac{100}{H_w} \quad \rightarrow \quad \text{Diagonal cracking} \quad K_{cr} = \text{cracked elastic stiffness}$$

$$R_{max} (\%) = a_1 \left(\frac{M}{V L} \right)^{b_1} \frac{V_{max}}{A_w \sqrt{f_c'}} + a_2 \left(\frac{M}{V L} \right)^{b_2} \quad \rightarrow \quad \text{Maximum shear strength}$$

$a_1 \dots b_2$ = depend on the type of web reinforcement; iterative regression analysis



Diagonal tension (DT) failure mode



DT, DC and DT-DC failures modes

Model equations

Displacement capacity: (in terms of drift ratio)

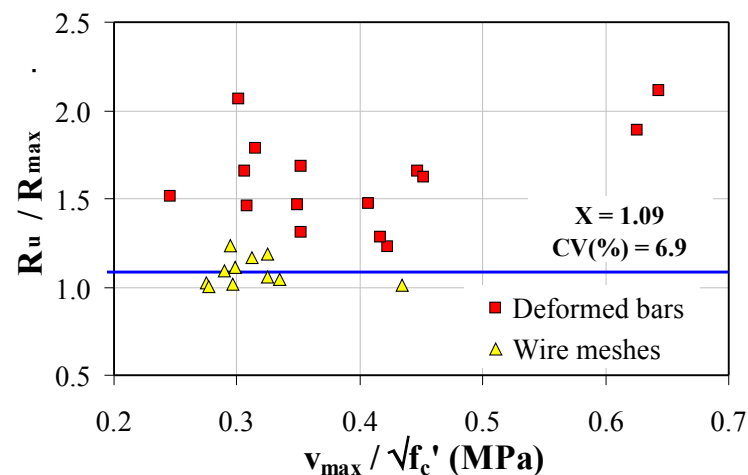
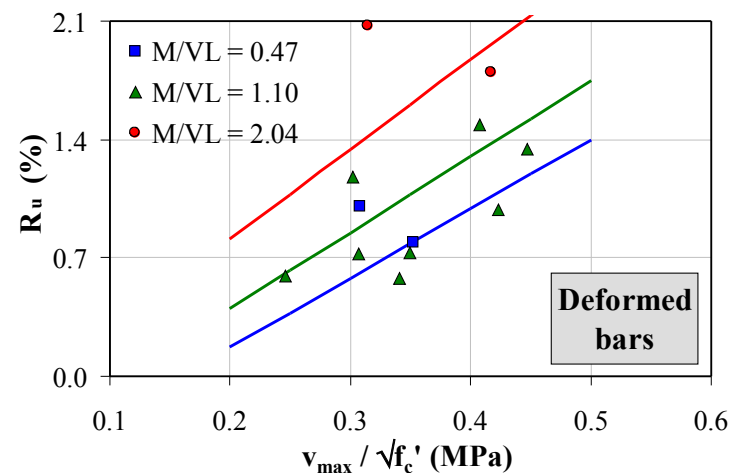
Ultimate → Deformed bars

$$R_u (\%) = c_1 \left(\frac{M}{V L} \right)^{d_1} \frac{V_{\max}}{A_w \sqrt{f_c'}} + c_2 \left(\frac{M}{V L} \right)^{d_2}$$

$c_1 \dots d_2 \rightarrow$ iterative regression analysis

Ultimate → Welded-wire meshes → Brittle failure mode

$$R_u (\%) = R_{\max} (\%)$$

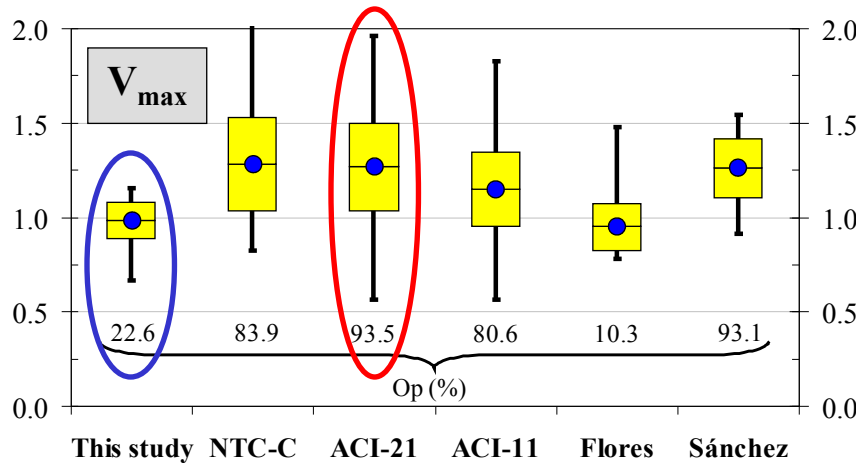


Evaluation of the prediction

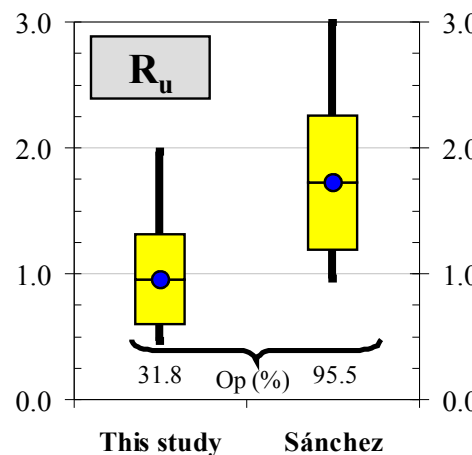
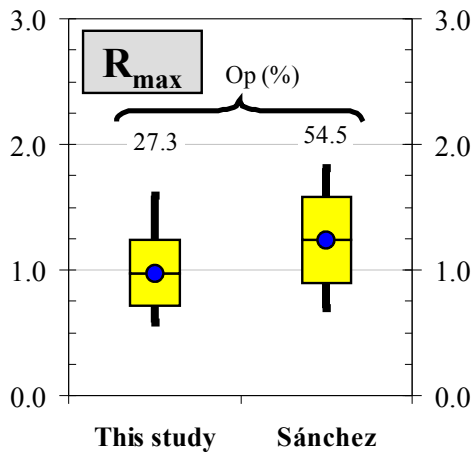
Statistical analysis: (predicted / observed)

$< 1.0 \rightarrow$ conservative
 $> 1.0 \rightarrow$ over-estimate
 (unsafe)

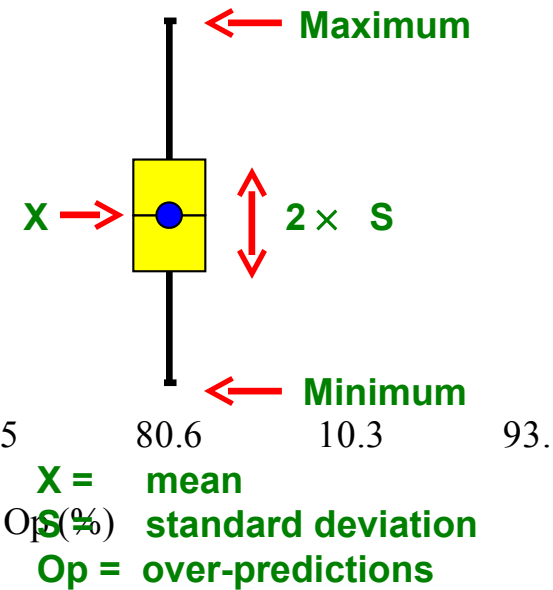
Strength capacity



Displacement capacity



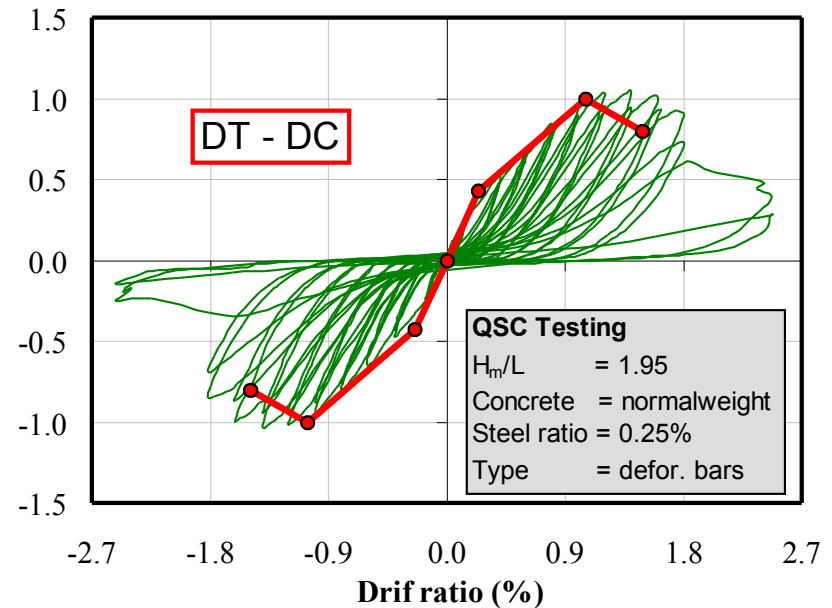
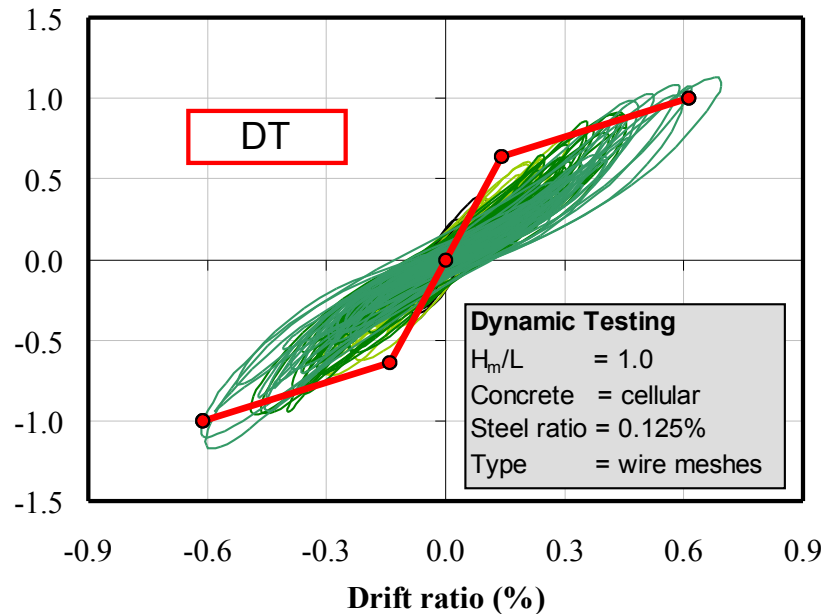
Modified Box and whisker charts



The predicted capacities are very similar to those measured, and the scatter is also lower than in the existing models.

Evaluation of the prediction

Measured hysteresis curves:



The proposed empirical model is capable of predicting the recorded seismic response with adequate accuracy.

- The *applicability* of the equations is limited to walls with the characteristics of RC walls for low-rise housing
- The equations that characterize three *performance levels* are intended to capture the average response from experiments
- Proposed equations have been calibrated on the basis of results observed not only from QS tests but also from *Dynamic tests*
- It is emphasized that the key merits of the proposed model are *simplicity and rationality*

Adopting the design model proposed herein, it would yield to a safer and more economic housing.

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Thank you EERI !

