ELEMENT 2

Field Investigations

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ASCE STRUCTURES CONGRESS

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CUREE-Caltech Woodframe Project

("Earthquake Hazard Mitigation of Woodframe Construction," funded by the Federal Emergency Management Agency through a grant administered by the California Governor's Office of Emergency Services)

ELEMENT 2

Field Investigations
includes:

Case Studies

by structural engineers
and

Statistical Investigations

based on LA City rapid screening and permit records

Case Studies

List of Case Studies

Chapter/ Case Study #	Authors	Project name	MMI	No. of Units	No. of stories Wood/Conc.
1	G G Schierle, Editor	Summary and Conclusions			
		Multifamily Dwellings (MFD)			
2	Seb Ficcadenti / Eric Freund	Sherman Court		132	3/2
3	Thomas Castle	Century Park Place Phase 2	VII	200	4/2
4	Thomas Castle / Lee Pursell	Dickens Street Condominiums		9	3/1
5	Seb Ficcadenti / Eric Freund	Northridge Apartments (2 buildings)		112	3/0
6	Seb Ficcadenti / Eric Freund	Northridge Meadows		163	3/0
7	Joel Wolf / Lisa Shusto	Sherman Oaks Building	IX	23	3/1
8	Joel Wolf / John Osteraas	Santa Clarita Complex (8 buildings)	VIII	148	2/0
9	Joel Wolf / John Osteraas	Northridge Complex (2 buildings)	IX	39	3/1
10	Dimitry Vergun	F	VIII	36	3/0
11	Dimitry Vergun	H	VIII	24	4/1
		Single Family Dwellings (SFD)			
12	Dimitry Vergun	G	VII	1	2/0
13	Dimitry Vergun	K	VII	1	2/0
14	Dimitry Vergun	O	VIII	1	2/0
15	Dimitry Vergun	R	VIII	1	2/0
16	Dimitry Vergun	S	VI	1	1/0
		Institutional			
17	Anthony Court	CSUN Satellite Student Union Center		1	2/0

Case Study Summary

- Poor quality control is most frequently cited
- Cracks in gyp board & stucco are major cost factors
- Nonstructural costs exceed structural costs
- Most SFD had masonry chimney failure
- Shear wall aspect ratio 3.5 to 1 per story for multistory buildings is flawed (case study 3)
- Irregular configurations caused diaphragm failure in case studies 5 & 6
- Great lower level stiffness increased upper level damage in several case studies

Nonstructural vs. Structural Damage and Vacancy Cost

	Cost as percentage of total [% = 100 (item cost / total repair cost)]							
Property type	MFD		SFD					CSUN
Case study #	10	11	12	13	14	15	16	17
Non-structural damage	93%	84%	55%	46%	76%	73%	70%	73%
Structural damage	7%	16%	45%	54%	24%	27%	30%	27%
Vacancy cost	3%	19%	14%	3%	19%	5%	0%	

- *Nonstructural damage exceeds structural damage*
- *Average nonstructural damage: 71% of total repair cost*
- *Average structural damage: 29% of total repair cost*
- *Average vacancy cost: 9% of total repair cost*

Table 1.2: Structural Damage Summary

Percent of damage [% = 100 (cost of item / total repair cost)]										
Case study number Items	**10**	**11**	**Average 10-11 (MFD)**	**12**	**13**	**14**	**15**	**16**	**Average 12-16 (SFD)**	**17**
Foundation	0.6	0	0.3	29.0	45.0		8.0	7.3	22.3	
Internal framing	1.4	1.5	1.5	1.8	0.6		0.7	4.8	2.0	
External framing	1.6	2.0	1.8	2.3	0.8		0.6	3.1	1.7	9.0
Floor framing	0.4	0	0.2	2.6	0.3		0.6	0.01	0.9	
Roof framing	0.4	0	0.2	0.3	0.1		0.6		0.3	
Int. sheathing	0.3	2.0	1.2	1.2	1.5		5.6		1.8	
Ext. sheathing	0.3	2.8	1.6	0.8	1.9		3.8		2.2	18.0
Floor sheathing	0.1	0.2	0.2	0.5	0.3		0.5		0.4	
Roof sheathing		0.1	0.1	0.2	0.1		0.4		0.2	
Miscellaneous	1.9	7.4	4.9	6.3	3.4		6.2	14.8	4.2	
Total	**7**	**16**	**12**	**45**	**54**	**24**	**27**	**30**	**36**	**27**

Table 1.3: Nonstructural Damage Summary

Percent of damage [% = 100 (cost of item / total repair cost)]										
Case study number Items	**10**	**11**	**Average 10-11 (MFD)**	**12**	**13**	**14**	**15**	**16**	**Average 12-16 (SFD)**	**17**
Interior finish	1.1	6.3	3.7	1.5	6.2		11.7	6.1		7.0
Exterior finish	12.6	7.4	10.0	3.7	7.9		12.4	8.6		31.5
Floor finish	15.7	5.9	10.8	2.8	2.3		7.4	2.0		
Roofing	4.1	2.5	3.3	1.2	0.5		0.7	2.0		0.9
Painting	5.9	4.8	5.4	2.8	2.7			3.0		
Doors	1.8	2.1	2.0	2.3	0.8		3.4	1.0		2.7
Windows	1.1	3.7	2.4	6.9	4.1		7.4	0.4		5.4
Cabinets	0.6	5.9	3.3	6.8	3.6			5.7		
Electrical	2.0	3.4	2.7	4.3	1.5		2.7	2.0		4.5
Mechanical	2.5	1.5	2.0	2.5	1.4		2.2	1.0		18.0
Plumbing	3.4	5.0	4.2	3.7	2.7			3.8		
Chimney		0.5	0.3	1.8	0.1			8.0		
Miscellaneous	42.2	35.0	37.9	14.7	12.2		25.1	26.4		3.0
Total	**93**	**84**	**88**	**55**	**46**	**76**	**73**	**70**		**73**

Case Study Recommendations

- Research needs:
  - Nonstructural items effect on dynamic behavior
  - Decoupling of finishes from plywood
  - Effect of increased stiffness on damage
  - Vertical force distribution for low-rise buildings
  - Effect of concrete slab creep on woodframe
  - Required width of seismic joints at intersections of irregular building wings
  - Required diaphragm reinforcement instead of joints at intersection of irregular building wings

- Building codes should:
  - Require designers to observe construction
  - Upgrade design of nonstructural items
  - Upgrade design of masonry chimneys
- Design guidelines should:
  - Recommend to anchor narrow multistory shear walls to edge beams, designed to resist overturn
  - Recommend seismic joints at junctions of wings of irregular buildings
  - Recommend seismic joints at architectural finishes to reduce the high cost earthquake repairs

Statistical Investigations

Categories:

- **2 Types: SFD & MFD** **(Singe Family & Multifamily Dwellings)**
- **3 PGA Intensities** **(<30; 30-60, >60 Peak Ground Acceleration)**
- **3 Vintages** **(Years built: 0-40; 41- 76; 77 – 93)**

Statistical Investigations

Categories:

- **2 Types: SFD & MFD** (Singe Family & Multifamily Dwellings)
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Studies:

- **General Study** (All yellow- and red-tagged projects)
- **Sample Study** (1230 random projects)
- **Tuck-under Parking** (42 Projects near Northridge Meadows)
- **Expensive Repair** (Projects estimated at = > 60 % damage)
- **Demolished Projects** (Projects demolished after earthquake)
- **NAHB Follow-up Study** (National Association of Home Builders)

Table 1-1: City Data Files of Northridge Earthquake Damage

Column index	A	B	F	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
LA County		E	E			E	E		E		E	E			E						
Los Angeles	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**
Beverly Hills	E	E	E			E	P					P			E						
Burbank		M	M	M		M	M	M				M			M	M	M	M	M	M	M
Glendale	n	o		d	a	t	a		a	v	a	i	l	a	b	l	e				
San Fernando	i	n	c	l	u	d	e	d		i	n		L	A		C	o	u	n	t	y
Santa Clarita		E	E				E	E	E			E			E						
Santa Monica	E	E	E			E						E			E						
Ventura County		P	P												P						
Calabasas		E	E			E	E				E	E			E						
Fillmore	P	P	P									P			P				P		P
Simi Valley	P	P	P	P		P						P			P				P		P

E = electronic file; M = microfiche; P = paper file

Column index:

A Record number
B Street number
F Street name
H Number of units
I Council district
J Damage type (EQ, fir, flood, etc.)
K Use (R = residential)
L Occupancy
M Number of dwelling units
N Number of units vacated
O Percent damage
P Repair cost
Q vacate building (P = partial, T = total)
R Permit required
S Posted (green, yellow, red)
T Number of stories
U Type of Construction (I, II, III, IV, V, URM)
V Approximate building dimensions
W Zip Code
X Year built
Y Description of repair job

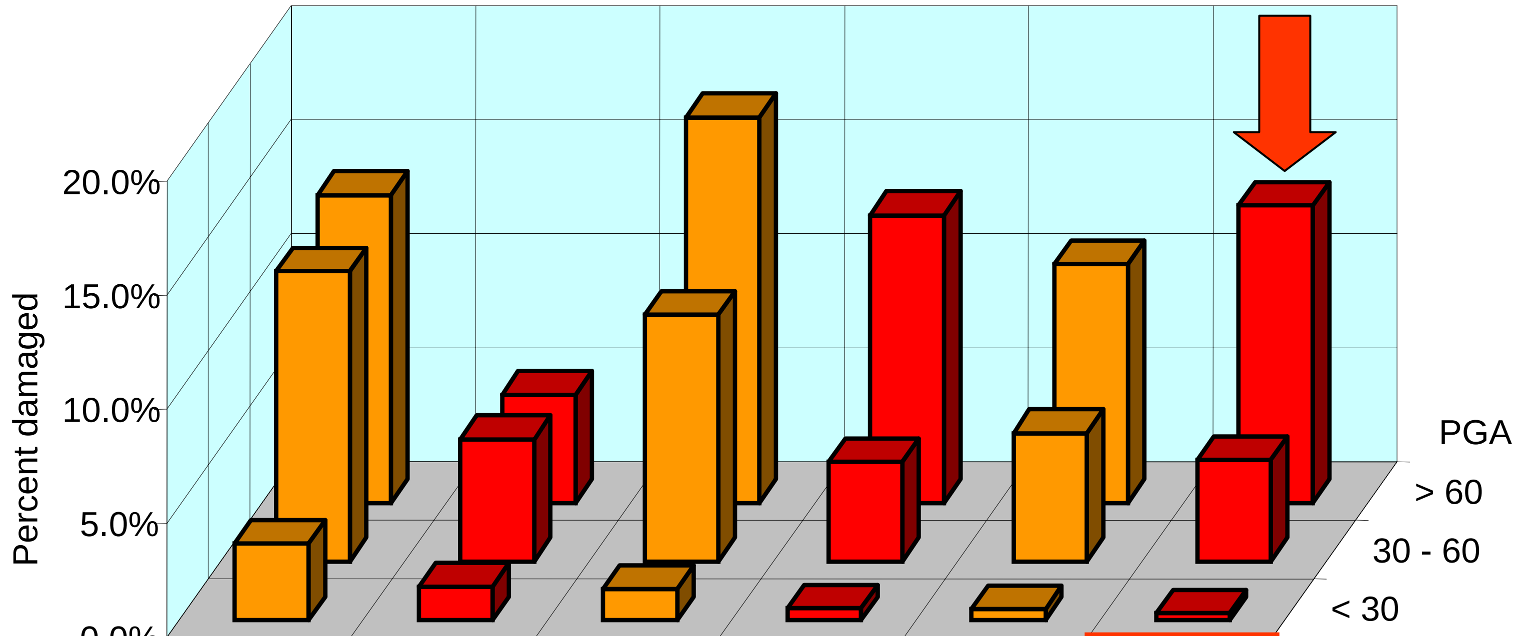
Statistical Investigation Summary

- Projects built since 1976 performed worst:
  - Highest % damaged MFD (General study)
  - Highest % damaged MFD & SFD (Expensive repair study)
  - Highest repair cost (tuck-under parking study)
  - Highest % demolished MFD
- Two-story are highest % demolished SFD
- Damage correlates better with PGA than PGV
- Hill sites have more damage than flat sites
- Non-structural damage is most costly at SFD
- Shear wall damage is most costly at MFD

Highest % damaged: MFD built since ’76

(General study)

Graph 2-2b: Damaged Projects as Percent of Existing

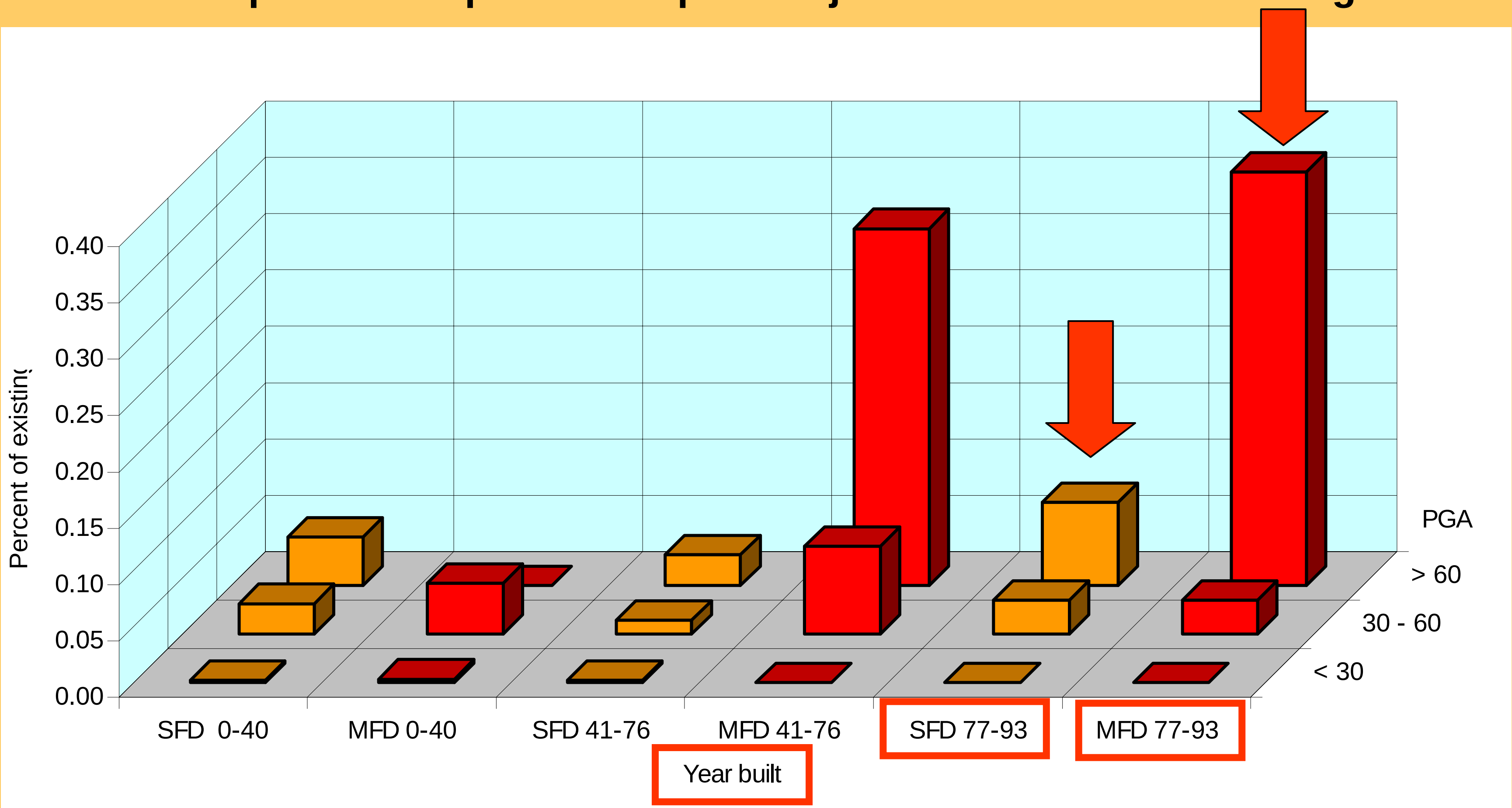


	SFD 0-40	MFD 0-40	SFD 41-76	MFD 41-76	SFD 77-93	MFD 77-93
< 30	3.4%	1.5%	1.4%	0.5%	0.5%	0.3%
30 - 60	12.7%	5.4%	10.8%	4.4%	5.6%	4.4%
> 60	13.5%	4.7%	16.9%	12.6%	10.4%	13.0%

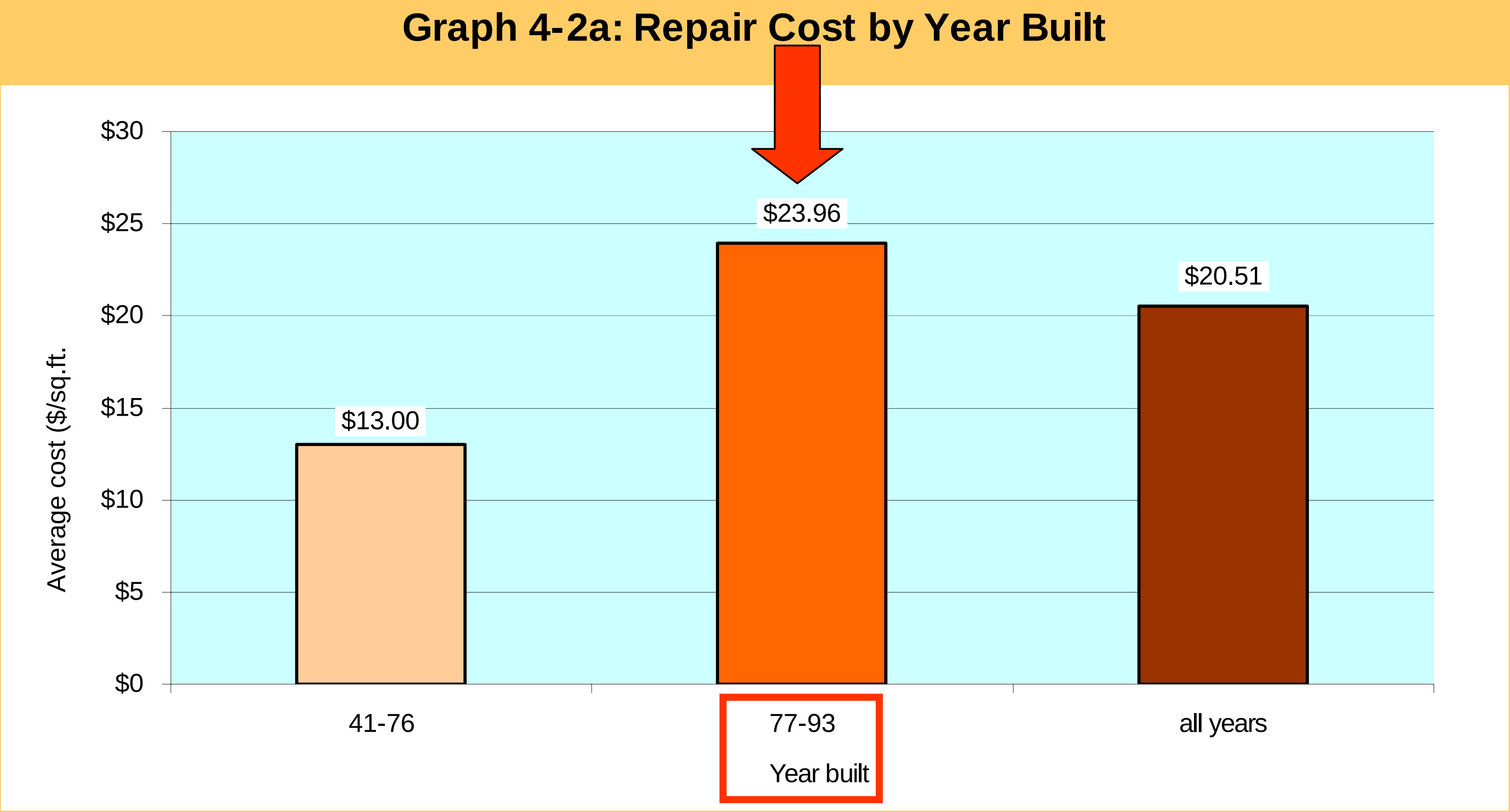
Year built / data table

Highest % damaged: MFD & SFD built since ‘76
(Expensive repair study)

Graph 5-1b: Expensive Repair Projects as Percent of Existing

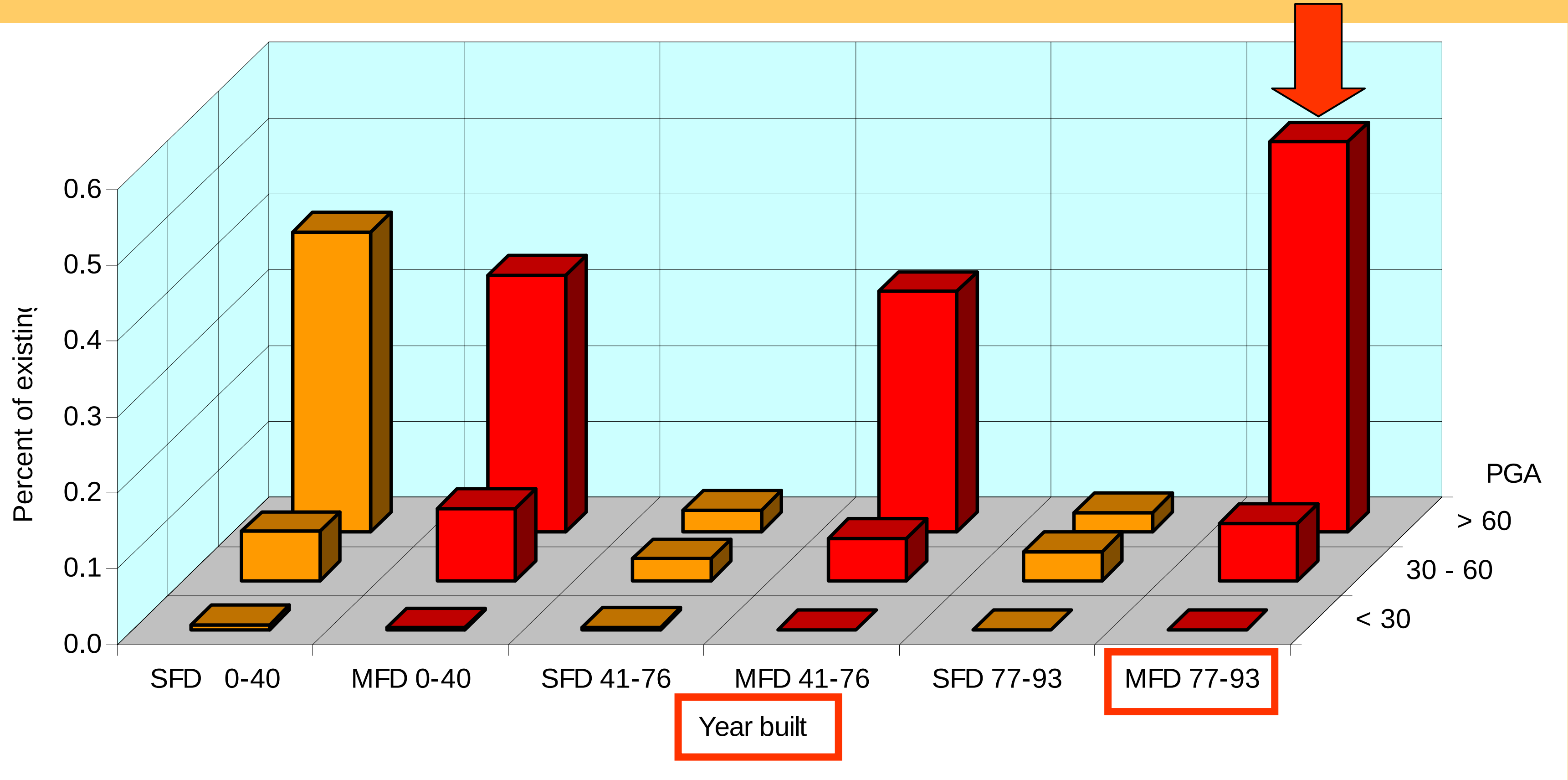


Highest repair cost: MFD built since ‘76
(Tuck-under parking study)

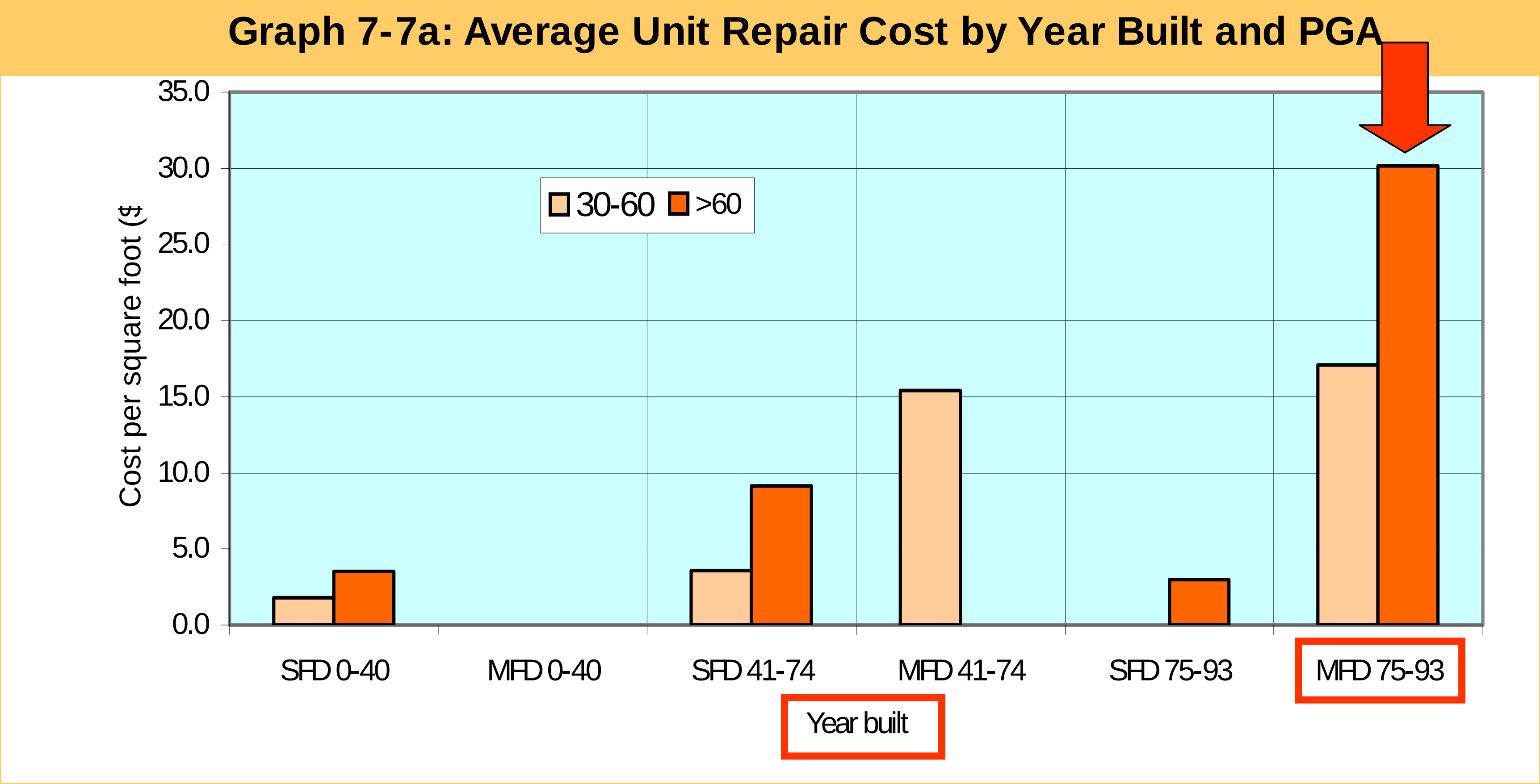


Highest % demolished: MFD built since ’76
(Demolished projects study)

Graph 6-1b: Demolished Projects as Percent of Existing by Year Built and PGA



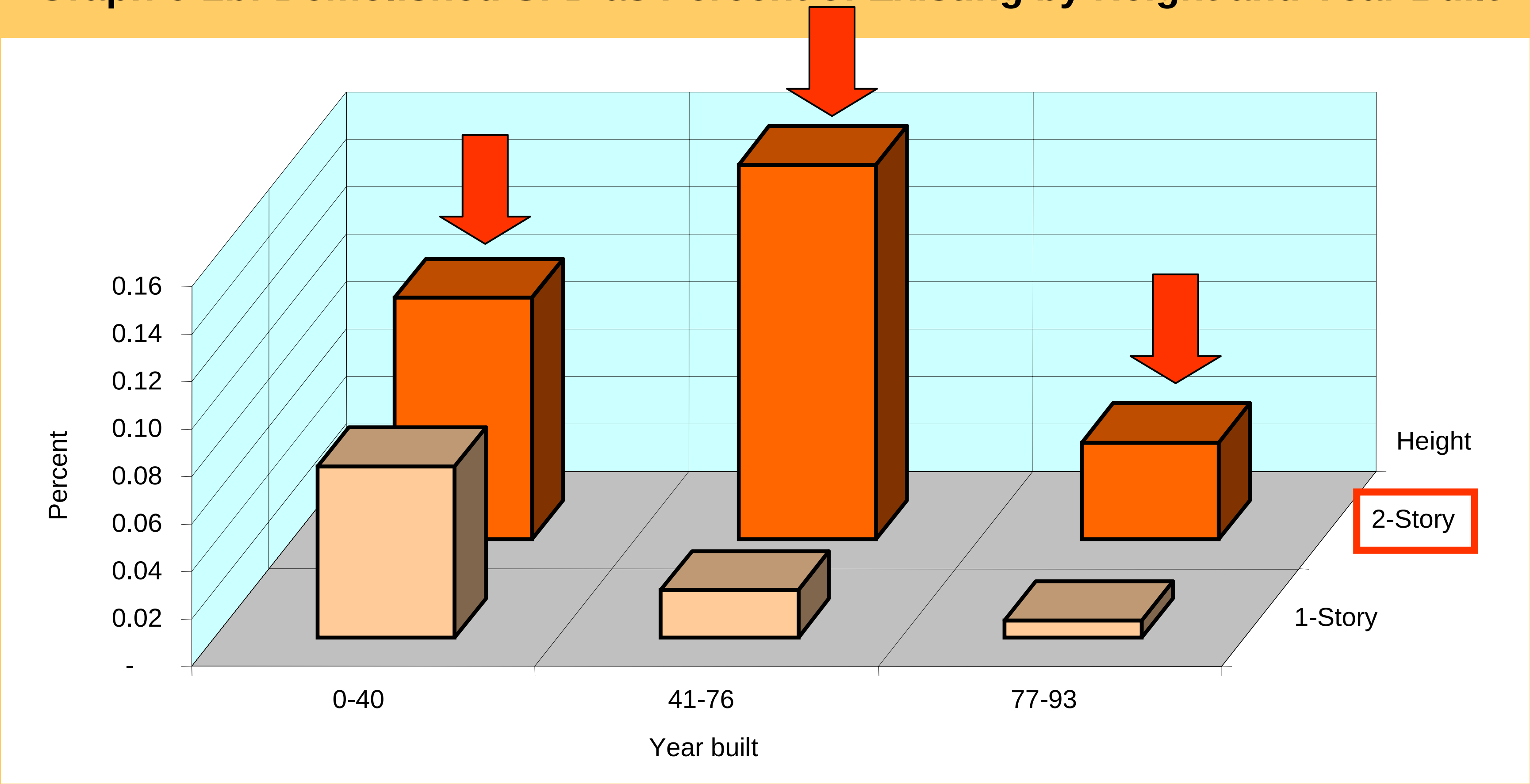
Highest repair cost: MFD built since '76
(NAHB follow-up study)



Two-story SFD have the highest % demolished

(Demolished projects study)

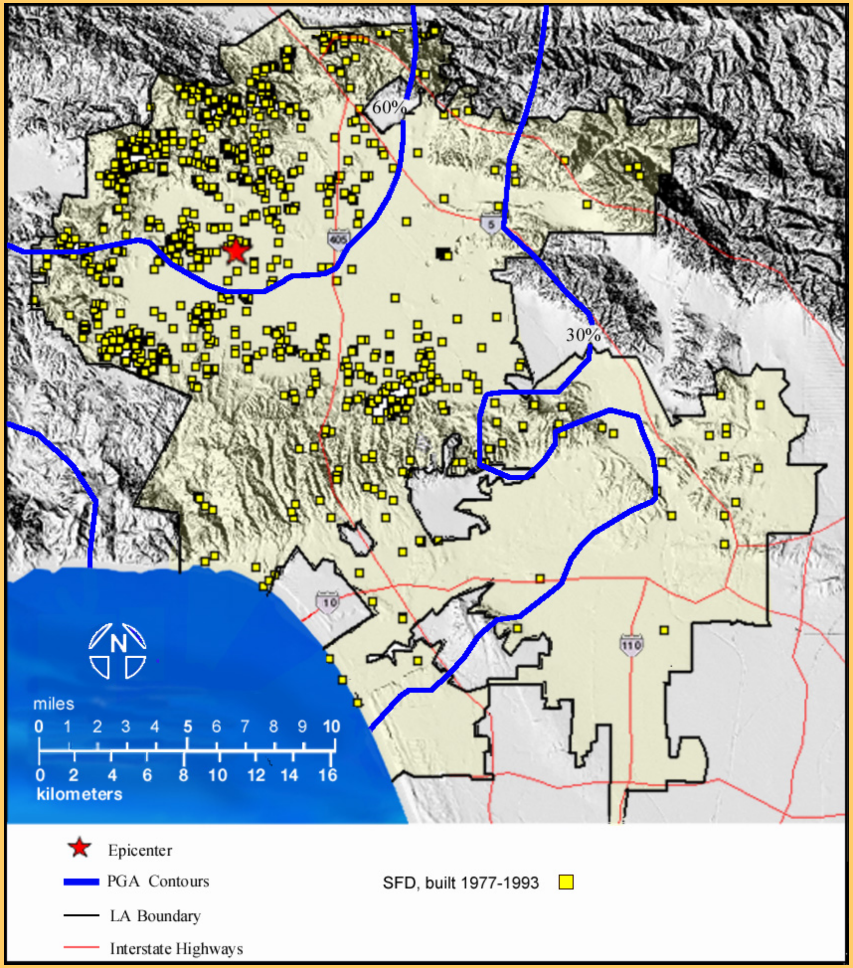
Graph 6-2b: Demolished SFD as Percent of Existing by Height and Year Built



The resonant period of about 0.2 seconds of 2-story SFD may have caused the failure

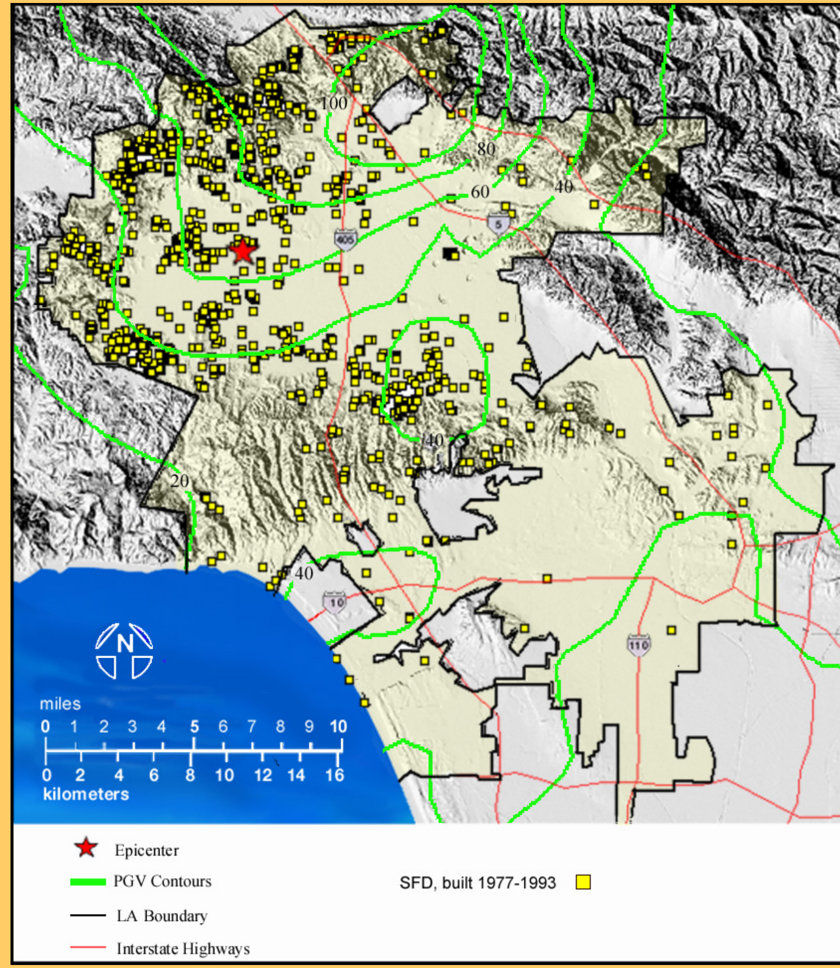
Damage correlates better with PGA than PGV

Map 2-5b: Damaged SFD, Built 77–93 at PGA Contours



PGA: Peak Ground Acceleration

Map 2-5b: Damaged SFD, Built 77–93 at PGV Contours



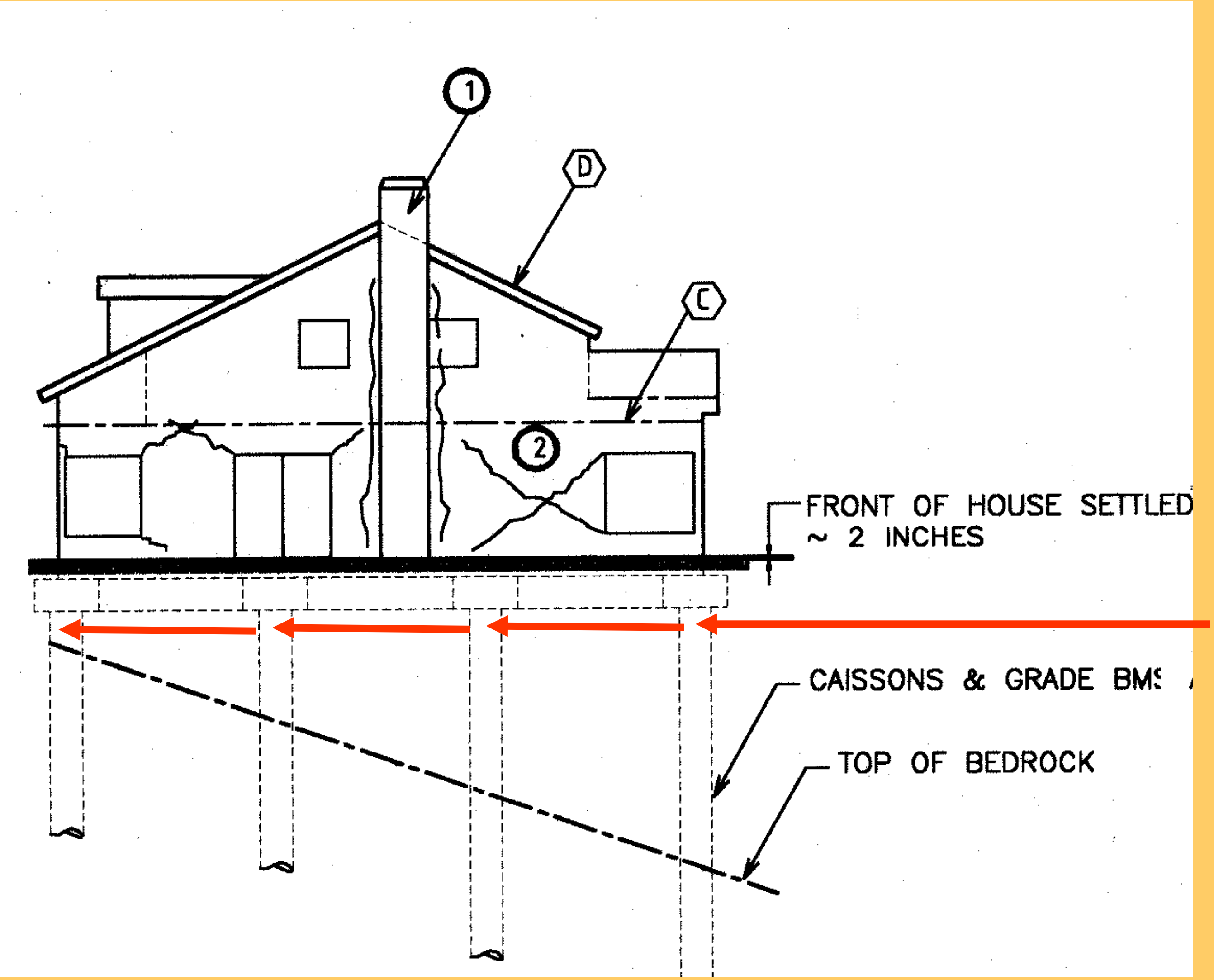
PGV: Peak Ground Velocity

Statistical Investigation Recommendations

- Rapid Screening should:
  - Record structure material not just type of construction which could be any material
  - Record structure material at different levels, such as wood framing over concrete garage

- Research should study:
  - Damage correlation with PGA vs. PGV
  - Effect of resonant building and site periods
  - Footing designs to reduce earthquake damage

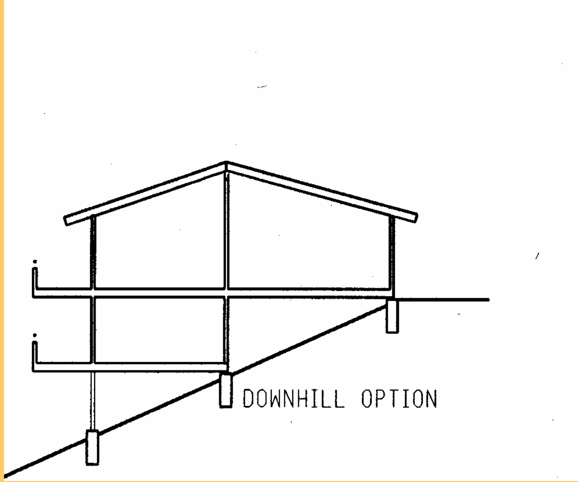
- Building codes should:
  - Upgrade shear wall design
  - Upgrade footing design
  - Upgrade chimney design
  - Upgrade exit stair design
  - Upgrade design of nonstructural items
  - Require designers to observe construction
  - Make seismic design objectives more transparent
- Design guidelines should:
  - Discourage heavy veneer on multistory buildings
  - Recommend to adapt hillside homes to the site to avoid differential fill settlements

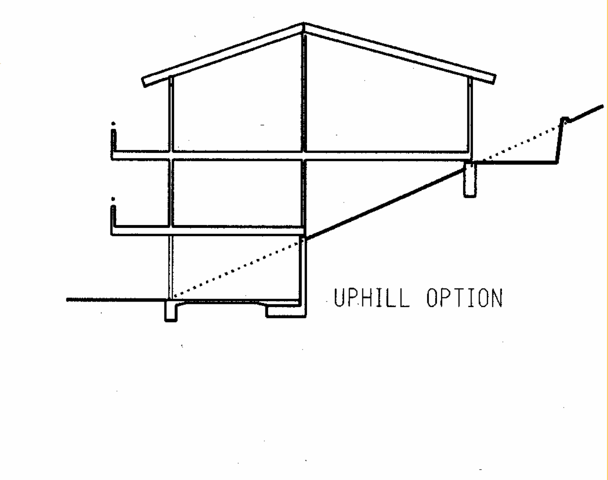


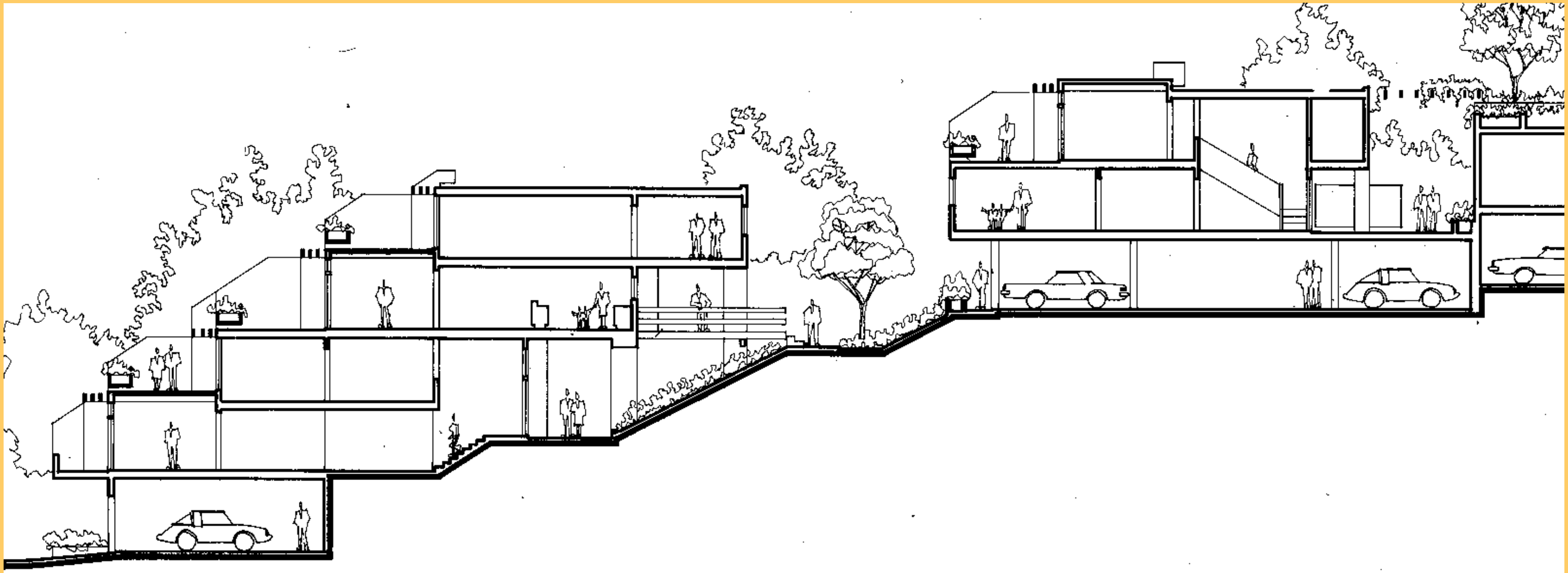
To avoid expensive earthquake settlement repair ……

Adapt building to site – instead of adapting site to building

… to reduce grading and retaining walls and avoid expensive settlement repairs ☺







Thank you