Earthquake Internet Information – Documentation Paper A

Development and Comparison of the ABAG Residential Structural Quiz Scoring for Earthquake Vulnerability with Other Available Scoring Systems

The Central Issue – Development of a Non-Technical System for Quantifying When Safety and Habitability of Housing Are At Risk

A major factor in convincing residential property owners and tenants that their residence may be unsafe, or that it may be uninhabitable following an earthquake, is to personalize that information in a way that relates both to personal safety and to risk to their own home or neighborhood. Research by ABAG indicates that this information is one of the key components in retrofit decision-making (Mikulis and others, 1999; Perkins and others, 1999). In the survey conducted as part of this ABAG research, the most commonly cited reason for doing structural retrofit work was, "I wanted to feel safer," mentioned by 55.9% of respondents. "I am concerned about damaging earthquakes in this home's neighborhood" was the next most common response, given by 54.5% of respondents. No other responses were cited by over 28% of the respondents. In addition, those that had viewed ABAG's ground shaking maps were over 60% more likely to have done a reasonably complete job of retrofitting their homes than those who had not seen ABAG's maps.

Thus, one major task of ABAG's outreach effort to residential property owners and tenants is to develop an entertaining, but reasonably accurate, means of "scoring" the potential level of safety and habitability risk associated with residential properties in the San Francisco Bay Area.

One objective of this task was to base the scoring system on questions that could be answered by a knowledgeable homeowner or tenant, rather than one trained in construction or engineering. Because the quiz is likely to be used by elderly who often own older homes, we use the model of the heart health (or risk factor) quizzes commonly seen in magazines to ask three-to-five key questions to develop a score.

At the same time, a second objective is for the scoring to not be inconsistent with that developed by others. There are two systems ***currently*** available to score wood-frame residential buildings: one developed by the City of San Jose for apartments (Vukazich, 1998), and another developed by the Applied Technology Council (ATC) for the Federal Emergency Management Agency (FEMA) (FEMA 154 or ATC 21) (Rojahn and Scawthorn, 2002, ***not the 1988 version***). FEMA 154 / ATC 21 is the only commonly available published scoring system for non-wood structures.

The following sections document the development of the point scores for the ABAG quiz and compare those scores to each of these two systems. Note that in the San Jose and FEMA 154 systems, the building starts out with a point score that is reduced by risk factors until it reaches a point score of 2.0 where an engineering evaluation is warranted. ***In a quick review of 20 quizzes located on the internet related to heart health or general health risk factors, in all cases the scores started at 0 and increased with the risk. Thus, the decision was made to use this more common means of indicating risk.***

In all of the ABAG quizzes, a 13-point threshold is used for recommending further action - retrofitting in the case of single-family homes, and contacting a structural engineer in the case of multifamily buildings. The threshold of 13 was selected because of its connotation as an "unlucky" number and because it made rough translations of scores from the San Jose and FEMA systems possible without resorting to decimal places in the points scored. ***In the same quick review of 20 quizzes located on the described earlier, in all cases the scores were in whole, not fractional, numbers.***

Occupants of buildings will scores of less than 13 points are ***NOT guaranteed*** to be without damage and occupants of these buildings can still be injured. The 13-point threshold is intended to indicate a significant probability of the residence being so damaged that it will be declared uninhabitable by a building department.

Scoring Shaking Hazard

The ABAG-developed scoring system in the internet residential quiz uses the modified Mercalli intensity associated with the largest earthquake affecting a particular area. In general, this composite map is generated by taking the "worst case" when the various shaking maps generated based on the latest U.S. Geological Survey probability report (USGS WG02, 2003) are compared. Three additional earthquake scenario maps are combined into the map, however: the Maacama fault (which some believe is a natural extension of the Rogers Creek fault in northern Sonoma County), the West Napa fault in southern Napa County, and the Monte Vista fault in western Santa Clara County. All three of these fault scenarios are not considered directly by USGS because not enough is known of their paleoseismicity and the recurrence interval of large earthquakes on these faults is considered to be relatively large. Rather, USGS considers their seismicity as part of the background shaking exposure in the region. ABAG, however, considers these faults in the "worst case" maps because of the known possibility that these earthquakes may occur.

The ABAG ground shaking scenario maps are used rather than the USGS ShakeMaps for several reasons:

- The shaking intensity of the areas closer to the fault is higher on the ABAG maps, a more conservative approach.
- The typical user of ABAG's Earthquake Program internet site is more familiar with the ABAG shaking maps.
- The ABAG map interface allows the user to zoom into their neighborhood, rather than viewing only the regional shaking intensity, and thus be more likely to be convinced that violent shaking is associated with their property location.

More information on how the ABAG shaking maps are generated is available from Perkins and Boatwright (1995) and Perkins (1998).

The ABAG points allocated for shaking exposure are consistently

- 7 for very strong, violent, or very violent (MMI VIII, IX, or X),
- 5 points for strong (MMI VII), and
- 3 points for moderate (MMI VI).

These points are much higher than those used in the San Jose scheme, but typically they still have minimal impact on whether or not a structural engineer should be contacted. In addition, 7 points is slightly over half of the points needed to reach the 13-point threshold for recommending further work. This assessment is consistent with the long-term message of ABAG that problems with residential buildings are a mixture of structural problems and shaking exposure.

The shaking hazard maps used by San Jose are the ABAG maps. The size of the correction factor assigned to these units is much smaller than in the ABAG scoring system, however, as noted above.

The shaking hazard is defined differently in the FEMA 154 approach to allow it to define risk through the country. First, the country is divided into three levels of seismicity - high, moderate, and low. All nine Bay Area counties are assigned ***high***. Second, the high seismicity areas are subdivided and scored with various risk levels based on the soils underlying the site, with hard rock (A) and average rock (B) having no corrections, while dense soil (C), stiff soil (D), and soft soil (E) are given various corrections to the scoring. Poor soil (F) is not given a correction factor. The size of this correction factor is generally higher for D than for C, and higher still for E. These correction factors apply to all of the residential building types ***except*** for the single-family home category (W1), which is not given a correction factor. The correction factors are also much smaller than in the ABAG scoring system, as noted above.

Scoring Soft Story Problems

Many residential buildings have a garage, parking structure, or commercial use as all or part of the first floor of the building. These soft stories have repeatedly had problems in past earthquakes. Thus, all of the scoring systems penalize buildings for having a parking or commercial use as part of the first floor. Other soft story problems, such as concrete shear walls that do not continue to the ground, are not addressed by the quiz in large part because they are not as common in residential buildings.

In the ABAG quiz, wood-frame homes are penalized 5 points for a split-level home and 4 points for a two-story home. (ABAG assumes that a garage is under a portion of these homes.) Wood-frame multifamily buildings are penalized 6 points for having a soft story, enough to trigger the recommendation of a structural evaluation in areas of high shaking hazard. In the San Jose scoring system, the penalty is also large enough to warrant a detailed structural evaluation of the building ***unless*** it was constructed after 1990 ***or*** the parking level is concrete or masonry.

Because the soft-story penalty is assessed prior to the question on type of material, the soft-story penalty remains 6 points for masonry and concrete/steel construction. The penalty in FEMA 154 is much smaller for non-wood construction than for wood-frame construction.

Scoring Other Configuration Irregularities

Residential buildings can have two other forms of configuration irregularities. First, wood-frame buildings can have unbraced or inadequately braced cripple walls. Buildings can also have irregularities in plan view (that is, be L-, T-, U-shaped, or surround an open courtyard). These irregularities have repeatedly caused problems in past earthquakes.

In the ABAG quiz, single-family wood-frame homes are penalized 3 points for having "3 or more steps to the front door" (with ABAG assuming that this height indicates the presence of a cripple wall). ABAG decided against asking whether or not a home has a “crawl space” because many homes constructed during the 1970s and 1980s have floor joists directly on a mud sill giving them a very short crawl space. Earlier homes commonly have a taller concrete “stem wall.” In both of these cases, the home is likely to only have two steps to the front door.

Wood-frame multifamily buildings are penalized 6 points for having a cripple wall, the same amount as for having a soft story. In the San Jose and FEMA 154 scoring systems, cripple walls are penalized by the same penalty as for a soft story. One difference is that the ABAG multifamily wood and San Jose penalties are cumulative – that is, a wood-frame apartment can have both a cripple wall and a soft story. The FEMA scores are only penalized once for having a "vertical irregularity."

The ABAG quiz asks the plan configuration question after the question on type of material. The wood-frame homes and apartments are not asked this question, and are not penalized. (ABAG’s approach may ***not*** be conservative for apartment buildings more than three times as long as they are wide and that that are be L-, T-, U-shaped, or surround an open courtyard. Addressing this issue did not seem critical because this type of configuration seemed rare.) For non-wood buildings, the ABAG penalty is 3 points. On the other hand, in the San Jose scoring system, plan irregularities in wood-frame buildings are penalized 40% of the amount of a soft story. The FEMA 154 penalty is 20-25% of the soft-story penalty for wood-frame buildings, and 33-50% of the soft-story penalty for non-wood buildings.

Scoring "Condition" of Structure

"Poor conditions" in residential buildings can include poor design, materials, workmanship, state of repair, non-code-compliant alterations, dry rot, insect damage, and settlement. ABAG data show that pre-1940s wood-frame homes are consistently poorer performers than more recent homes (Perkins and Chuaqui, 1997). On the other hand, some data compiled after the 1994 Northridge earthquake by EQE for OES (1995) indicate that newer homes can have more problems than those built in the 1950s and 1960s due to poor condition. The only way to account for these is to ask qualified contractors or design professionals to look for their telltale signs.

The 1988 version of FEMA 154 penalizes structures in poor condition. Similarly, the San Jose scoring system penalizes a structure in poor condition approximately 20% of the amount of a cripple wall or soft-story problem. In the 2002 version of FEMA 154, the structural condition modifier is no longer used. The ABAG scoring system also does not include a question about structural condition, in part because of the difficulty of having a non-professional assess such conditions. In addition, it is far more likely that a tenant might believe that a building is in "poor condition" than the owner.

Wood-Frame Single Family Homes and Duplexes

Wood-frame single family homes and duplexes are category W1 in the FEMA 154 classification scheme - wood-frame structures of less than 5,000 square feet.

The simplest way to compare the scores obtained using the ABAG system versus FEMA 154 is to run four hypothetical homes:

- a 1920s one-story house with a cripple wall that is assumed to be not bolted to its foundation,
- a 1950s split-level home with a cripple wall,
- a 1960s home on a concrete slab, and
- an early 1980s two-story home.

The following table compares the scores for these four homes in three areas of the region - Oakland (as an example of highest intensity), the hills of Lafayette (as an example of intensity VII), and Dixon (as an example of intensity (VI). There is only one column for FEMA 154 in this table because, for this building type, there is no correction for soil type within areas of HIGH seismicity. FEMA 154 penalizes homes for being built prior to 1941, and provides bonus points for homes constructed after 1976.

The ABAG scores are more conservative in the areas of violent and strong shaking but less conservative in the areas of moderate shaking exposure.

TABLE 1: Approximate Relationships Between ABAG and FEMA 154 Scores for Single-Family Homes (FEMA Building Type W1)

TABLE 1 NOTE – The recommendation in the ABAG scoring system is for the owner to evaluate the building and probably retrofit if the score is 13 or more (using the services of a structural engineer or other design professional for larger or more complex homes). The recommendation in the FEMA scoring system is for the owner to hire a structural engineer if the home scores below 2. Thus, for ease of comparison, the scores where more work is recommended are shaded.

Wood-Frame House Type	ABAG Score Violent Shaking Exposure (MMI VIII, IX or X)	ABAG Score Strong Shaking Exposure (MMI VII)	ABAG Score Moderate Shaking Exposure (MMI VI)	FEMA 154 Score For Building Type W1 (all MMI values)
1920s rectangular one-story house with a cripple wall	**16**	**14**	**12**	**1.9**
1950s rectangular split-level home with a cripple wall	**18**	**16**	**14**	**1.9**
1950s L-shaped split-level home with a cripple wall	**18**	**16**	**14**	**1.4**
1960s L-shaped home on a concrete slab	**11**	**9**	**7**	**3.9**
early 1980s rectangular two-story home	**13**	**11**	**9**	**6.4**

Wood-Frame Multifamily Apartments and Townhouses

Wood-frame multifamily homes generally exceed the 5,000 square foot floor area cut off between W1 and W2 in the FEMA 154 classification scheme. Thus, the following comparison is made between the ABAG scoring system and FEMA 154 category W2. In addition, the San Jose scoring system is also compared.

Again, a variety of buildings are compared. The nineteen structures are for three age categories, two plan configurations, with and without a soft-story (parking or tuck-under parking on the ground floor), and three building heights (one-story, two-story, and four-story buildings). The oldest buildings to be inadequately bolted to their foundations.

For this building type, there is a small correction for soil type within areas of HIGH seismicity in the FEMA scoring system. The San Jose scoring system uses the ABAG intensity maps, so comparisons are simple.

The scoring comparison is shown on Table 2 on the facing page.

TABLE 2 NOTE: The recommendation in the ABAG scoring system is for the owner to contact a structural engineer or other design professional for further evaluation if the score is 13 or more. The recommendation in the FEMA and San Jose scoring system is for the owner to hire a structural engineer or other design professional if the home scores below 2. Thus, for ease of comparison, the scores where contacting an engineer is recommended are shaded in Table 2.

For buildings constructed prior to 1976, the ABAG scores are the most conservative in the areas exposed to violent shaking, but less conservative for buildings with moderate shaking exposure. For buildings constructed after 1976 but before 1990, both the San Jose scores and the ABAG scores are significantly more conservative than the FEMA scores. Only for two-story apartments with soft stories exposed to strong or moderate shaking are the ABAG scores less conservative than the San Jose scores. In addition, because the ABAG scores do not improve in 1990, the scores are also more conservative than the San Jose scores during this time period.

TABLE 2: Approximate Relationships Among ABAG, FEMA 154, and San Jose Scores for Multifamily Residential Buildings (FEMA Building Type W2)

	ABAG Score			FEMA 154 Score				San Jose Score		
Wood-Frame Residential Building Type	**Violent Shaking Exposure (MMI VIII, IX or X)**	**Strong Shaking Exposure (MMI VII)**	**Moderate Shaking Exposure (MMI VI)**	**Building Type W2 - HIGH Seismicity: Unmodified for Soil Type**	**Soil Type C (Dense Soil)**	**Soil Type D (Stiff Soil)**	Soil Type E (Soft Soil)	**Violent Shaking Exposure (MMI VIII, IX or X)**	**Strong Shaking Exposure (MMI VII)**	**Moderate Shaking Exposure (MMI VI)**
1960 rectangular one-story apartment on a slab	9	7	5	3.8	3.4	3	3.0	3.6	3.9	4.2
1960 irregular one-story apartment on a slab	9	7	5	3.3	2.9	2.5	2.5	2.6	2.9	3.2
1960 rectangular one-story apartment with a cripple wall	15	13	11	1.8	1.4	1	1.0	1.1	1.4	1.7
1960 rectangular two-story apartment with soft story	18	16	14	1.8	1.4	1	1.0	1.1	1.4	1.7
1960 irregular two-story apartment with soft story	18	16	14	1.3	0.9	0.5	0.5	0.1	0.4	0.7
1960 rectangular two-story apartment with a cripple wall	18	16	14	1.8	1.4	1	1.0	1.1	1.4	1.7
1978 rectangular one-story apartment on a slab	9	7	5	6.2	5.8	5.4	5.4	3.6	3.9	4.2
1978 irregular one-story apartment on a slab	9	7	5	5.7	5.3	4.9	4.9	2.6	2.9	3.2
1978 rectangular two-story apartment on a slab	12	10	8	6.2	5.8	5.4	5.4	3.6	3.9	4.2
1978 rectangular two-story apartment with soft story	18	16	14	4.2	3.8	3.4	3.4	1.1	1.4	1.7
1978 irregular two-story apartment with soft story	18	16	14	3.7	3.3	2.9	2.9	0.1	0.4	0.7
1978 rectangular four-story apartment with soft story	21	19	17	4.2	3.8	3.4	3.4	1.1	1.4	1.7
1978 irregular four-story apartment with soft story	21	19	17	3.7	3.3	2.9	2.9	0.1	0.4	0.7
1992 rectangular one-story apartment on a slab	9	7	5	6.2	5.8	5.6	5.4	5.6	5.9	6.2
1992 irregular one-story apartment on a slab	9	7	5	5.7	5.3	5.1	4.9	4.6	4.9	5.2
1992 rectangular two-story apartment with soft story	18	16	14	4.2	3.8	3.6	3.4	3.1	3.4	3.7
1992 irregular two-story apartment with soft story	18	16	14	3.7	3.3	3.1	2.9	2.1	2.4	2.7
1992 rectangular four-story apartment with soft story	21	19	17	4.2	3.8	3.6	3.4	3.1	3.4	3.7
1992 irregular four-story apartment with soft story	21	19	17	3.7	3.3	3.1	2.9	2.1	2.4	2.7

Unreinforced Masonry Multifamily Apartments and Townhouses

All unreinforced masonry buildings are grouped together in the ABAG scoring system, including those with steel frame or concrete frames and unreinforced masonry infill. Thus, this category includes the URM, S5, and C3 designations in the FEMA 154 classification scheme. The San Jose scoring system does not apply to unreinforced masonry residential buildings so no comparison with that system is included in the analysis of this type of construction.

Again, a variety of buildings are compared. The 23 structures are all assumed to be built in 1920 (thus, "pre-code"). In addition, they are for two plan configurations, with and without a soft-story (typically a building with an open front and commercial space on the ground floor), and five story heights (one-story, two-story, three-story, five-story, and eight-story buildings).

For these building types, there is a small correction for soil type within areas of HIGH seismicity in the FEMA scoring system. Thus, the table includes scoring for the various FEMA soil types.

The scoring comparison is shown on Table 3 on the facing page.

TABLE 3 NOTE: The recommendation in the ABAG scoring system is for the owner to contact a structural engineer or other design professional for further evaluation if the score is 13 or more. The recommendation in the FEMA scoring system is for the owner to hire a structural engineer or other design professional if the home scores below 2. Thus, for ease of comparison, the scores where contacting an engineer is recommended are shaded in Table 3.

Using the ABAG scoring system, all of the buildings have scores greater than 13, and thus the owners are advised to hire a structural engineer. (In addition, in the discussion of masonry on the web site, the fact that most retrofitting that has occurred on these buildings focuses on "life safety" versus "habitability" is emphasized.)

The FEMA scoring system also gives scores to the URM buildings that would lead an owner to hire a structural engineer (scores less than 2). On the other hand, some of the steel frame buildings with unreinforced masonry achieve scores greater than 2. This discrepancy is not considered a significant problem because it would be rare for an owner to be aware of a steel frame in a building. If such a frame exists, the engineer should be able to identify it.

TABLE 3: Approximate Relationships Between ABAG and FEMA 154 Scores for Multifamily Unreinforced Masonry Residential Buildings (FEMA Building Types URM, C3, and S5)

Unreinforced Masonry Residential Building Type	ABAG Score: Violent Shaking Exposure (MMI VIII, IX or X)	ABAG Score: Strong Shaking Exposure (MMI VII)	ABAG Score: Moderate Shaking Exposure (MMI VI)	FEMA 154 Score, Building Types URM, S5, and C3 - HIGH Seismicity: Unmodified for Soil Type	Soil Type C (Dense Soil)	Soil Type D (Stiff Soil)	Soil Type E (Soft Soil)
1920 rectangular one-story URM apartment	21	19	17	1.6	1.2	1.0	0.8
1920 irregular one-story URM apartment	24	22	20	1.1	0.7	0.5	0.3
1920 rectangular three-story URM apartment	21	19	17	1.6	1.2	1.0	0.8
1920 rectangular three-story URM apartment with soft story	27	25	23	0.6	0.2	0	-0.2
1920 irregular three-story URM apartment with soft story	30	28	26	0.1	-0.3	-0.5	-0.7
1920 rectangular five-story URM apartment	21	19	17	1.6	1.2	1.0	0.8
1920 irregular five-story URM apartment	24	22	20	1.1	0.7	0.5	0.3
1920 irregular five-story URM apartment with soft-story	30	28	26	0.1	-0.3	-0.5	-0.7
1920 rectangular three-story C3 apartment	21	19	17	1.4	1.0	1.0	0.6
1920 rectangular three-story C3 apartment with soft story	27	25	23	0.4	0	0	-0.4
1920 irregular three-story C3 apartment with soft story	30	28	26	-0.1	-0.5	-0.5	-0.9
1920 rectangular five-story C3 apartment	21	19	17	1.6	1.2	1.2	0.8
1920 rectangular five-story C3 apartment with soft story	27	25	23	0.6	0.2	0.2	-0.2
1920 irregular five-story C3 apartment with soft story	30	28	26	0.1	-0.3	-0.3	-0.7
1920 rectangular three-story S5 apartment	21	19	17	1.8	1.4	1.4	1.0
1920 rectangular three-story S5 apartment with soft story	27	25	23	0.8	0.4	0.4	0
1920 irregular three-story S5 apartment with soft story	30	28	26	0.3	-0.1	-0.1	-0.5
1920 rectangular five-story S5 apartment	21	19	17	2.2	1.8	1.8	1.4
1920 rectangular five-story S5 apartment with soft story	27	25	23	1.2	0.8	0.8	0.4
1920 irregular five-story S5 apartment with soft story	30	28	26	0.7	0.3	0.3	-0.1
1920 rectangular eight-story S5 apartment	20	18	16	2.6	2.2	2.2	1.8
1920 rectangular eight-story S5 apartment with soft story	26	24	22	1.6	1.2	1.2	0.8
1920 irregular eight-story S5 apartment with soft story	29	27	25	1.1	0.7	0.7	0.3

Reinforced Masonry Multifamily Apartments and Townhouses

All reinforced masonry buildings are grouped together in the ABAG scoring system, including those with rigid and flexible diaphragms (floors and roofs of concrete versus wood). Thus, this category includes the RM1 (flexible diaphragms) and RM2 (rigid diaphragms) designations in the FEMA 154 classification scheme. The San Jose scoring system does not apply to reinforced masonry residential buildings so no comparison with that system is included in the analysis of this type of construction.

Again, a variety of buildings are compared. The 26 structures are assumed to be built in 1950, 1970, or 1980 (post-benchmark according to ATC 154). In addition, they are for two plan configurations (rectangular and L-shaped), with and without a soft-story (parking or open commercial space on the ground floor), and four story heights (one-story, three-story, five-story, and eight-story buildings). Note that soft-story reinforced masonry buildings are quite rare. This configuration is included to aid in the comparison of the ABAG and FEMA 154 scoring systems.

For these building types, there is a small correction for soil type within areas of HIGH seismicity in the FEMA scoring system. Thus, the table includes scoring for the various FEMA soil types.

The scoring comparison is shown on Table 4 on the facing page.

TABLE 4 NOTE: The recommendation in the ABAG scoring system is for the owner to contact a structural engineer or other design professional for further evaluation if the score is 13 or more. The recommendation in the FEMA scoring system is for the owner to hire a structural engineer or other design professional if the home scores below 2. Thus, for ease of comparison, the scores where contacting an engineer is recommended are shaded in Table 4.

The ABAG system agrees with FEMA 154 in almost all cases except when buildings produced post-benchmark (post 1976) are evaluated. FEMA 154 is significantly less cautious when recommending further evaluations of these buildings than ABAG, due, in part, to a concern that the user may be mistaking a concrete building for a masonry one. In addition, ABAG penalizes configuration characteristics such as a soft story and irregular base shape more heavily than FEMA 154.

TABLE 4: Approximate Relationships Between ABAG and FEMA 154 Scores for Multifamily Reinforced Masonry Residential Buildings (FEMA Building Types RM1 and RM2)

Reinforced Masonry Residential Building Type	ABAG Score Violent Shaking Exposure (MMI VIII, IX or X)	Strong Shaking Exposure (MMI VII)	Moderate Shaking Exposure (MMI VI)	FEMA 154 Score Building Types RM1 or RM2 - HIGH Seismicity Unmodified for Soil Type	Soil Type C (Dense Soil)	Soil Type D (Stiff Soil)	Soil Type E (Soft Soil)
1950 rectangular one-story RM1 apartment	12	10	8	2.8	2.4	2.2	2.4
1950 irregular one-story RM1 apartment	15	13	11	2.3	1.9	1.7	1.9
1950 rectangular three-story RM1 apartment	12	10	8	2.8	2.4	2.2	2.4
1950 rectangular three-story RM1 apartment with soft story w/ soft story	18	16	14	1.8	1.4	1.2	1.4
1950 irregular three-story RM1 apartment with soft story	21	19	17	1.3	0.9	0.7	0.9
1950 rectangular five-story RM2 apartment	10	8	6	3.2	2.8	2.6	2.6
1950 irregular five-story RM2 apartment	13	11	9	2.7	2.3	2.1	2.1
1950 irregular five-story RM2 apartment with soft-story	19	17	15	1.7	1.3	1.1	1.1
1970 rectangular three-story RM2 apartment	12	10	8	2.8	2.4	2.2	2.2
1970 rectangular three-story RM2 apartment with soft story	18	16	14	1.8	1.4	1.2	1.2
1970 irregular three-story RM2 apartment with soft story	21	19	17	1.3	0.9	0.7	0.7
1970 rectangular five-story RM2 apartment	10	8	6	3.2	2.8	2.6	2.6
1970 rectangular five-story RM2 apartment with soft story	16	14	12	2.2	1.8	1.6	1.6
1970 irregular five-story RM2 apartment with soft story	19	17	15	1.7	1.3	1.1	1.1
1970 rectangular eight-story RM2 apartment	10	8	6	3.4	3	2.8	2.8
1970 rectangular eight-story RM2 apartment with soft story	16	14	12	2.4	2.0	1.8	1.8
1970 irregular eight-story RM2 apartment with soft story	19	17	15	1.9	1.5	1.3	1.3
1980 rectangular three-story RM2 apartment	5	3	1	5.8	5.4	5.2	5.2
1980 rectangular three-story RM2 apartment with soft story	11	9	7	4.8	4.4	4.2	4.2
1980 irregular three-story RM2 apartment with soft story	14	12	10	4.3	3.9	3.7	3.7
1980 rectangular five-story RM2 apartment	3	1	-1	6.2	5.8	5.6	5.6
1980 rectangular five-story RM2 apartment with soft story	9	7	5	5.2	4.8	4.6	4.6
1980 irregular five-story RM2 apartment with soft story	12	10	8	4.7	4.3	4.1	4.1
1980 rectangular eight-story RM2 apartment	3	1	-1	6.4	6	5.8	5.8
1980 rectangular eight-story RM2 apartment with soft story	9	7	5	5.4	5.0	4.8	4.8
1980 irregular eight-story RM2 apartment with soft story	12	10	8	4.9	4.5	4.3	4.3

Concrete and Steel Multifamily Apartments and Townhouses

All concrete, steel, and pre-cast concrete buildings are grouped together in the ABAG scoring system including all variations on the designs. Thus, this category includes the C1, C2, S1, S2 and PC2 designations in the FEMA 154 classification scheme. The San Jose scoring system does not apply to steel or concrete residential buildings so no comparison with that system is included in the analysis of this type of construction.

The likelihood of the average landlord or tenant to be able to recognize the difference between varying steel and concrete structures is very slim. As such, the ABAG system varies its scoring based on year and building height to reflect a conservative analysis of the most likely building type. The structure type reflected is based off of the ATC 154 tables of most likely structural types for a given story-height and age (see Rojahn and Scawthorne, 2002, pp. 92-93).

TABLE 5: Assignment of Concrete/Steel ABAG Material Group to FEMA 154 Material Group Based on Year of Construction and Number of Stories

	# of Stories			
Year	**1**	**2 to 3**	**4 to 6**	**7+**
<1930	X	X	X	X
1930-1945	X	X	S1	S1
1945-1960	X	X	C1	C1
1961-1978	C1	C1	C1	C1
1979-2003	C1	C1	C1	C1

For these building types, there is a small correction for soil type within areas of HIGH seismicity in the FEMA scoring system. Thus, the table includes scoring for the various FEMA soil types.

The scoring comparison is shown on Table 6 on the facing page for a variety of dates of construction, number of stories, and configurations. Although some of these building types are rare, the scores are calculated to aid in comparing the ABAG and FEMA 154 scoring systems.

TABLE 6 NOTE: The recommendation in the ABAG scoring system is for the owner to contact a structural engineer or other design professional for further evaluation if the score is 13 or more. The recommendation in the FEMA scoring system is for the owner to hire a structural engineer or other design professional if the home scores below 2. Thus, for ease of comparison, the scores where contacting an engineer is recommended are shaded in Table 6.

The ABAG system agrees with FEMA 154 in almost all cases except for taller steel frame buildings and non-ductile concrete frame buildings. In the 1988 version of FEMA 154, taller buildings were penalized due, in part, to being heavier. In the more recent 2002 version, taller buildings are felt to perform better due to more careful design. The ABAG scoring system neither penalizes, nor gives credit, to taller buildings.

TABLE 6: Approximate Relationships Between ABAG and FEMA 154 Scores for Multifamily Concrete and Steel Residential Buildings (FEMA Building Types C1, C2, S1, S2, and PC2)

Concrete/Steel Residential Building Type	ABAG Score Violent Shaking Exposure (MMI VIII, IX or X)	Strong Shaking Exposure (MMI VII)	Moderate Shaking Exposure (MMI VI)	FEMA 154 Score Building Types C1, S1, or PC2 - HIGH Seismicity Unmodified for Soil Type	Soil Type C (Dense Soil)	Soil Type D (Stiff Soil)	Soil Type E (Soft Soil)
1944 rectangular five-story S1	13	11	9	3.0	2.6	2.4	1.8
1944 rectangular five-story S1 with soft story	19	17	15	2.0	1.6	1.4	0.8
1944 five-story irregular S1 with soft story	22	20	18	1.5	1.1	0.9	0.3
1944 rectangular eight-story S1	13	11	9	3.4	3.0	2.8	2.2
1944 rectangular eight-story S1 with soft story	19	17	15	2.4	2.0	1.8	1.2
1944 eight-story irregular S1 with soft story	22	20	18	1.9	1.5	1.3	0.7
1970 one-story C1	15	13	11	2.5	2.1	1.9	1.3
1970 one-story irregular C1	18	16	14	2.0	1.6	1.4	0.8
1970 rectangular three-story C1	15	13	11	2.5	2.1	1.9	1.3
1970 rectangular three-story C1 with soft story	21	19	17	1.0	0.6	0.4	-0.2
1970 rectangular three-story irregular C1 with soft story	24	22	20	0.5	0.1	-0.1	-0.7
1970 rectangular five-story C1	15	13	11	2.9	2.5	2.3	1.7
1970 rectangular five-story C1 with soft story	21	19	17	1.4	1.0	0.8	0.2
1970 five-story irregular C1 with soft story	24	22	20	0.9	0.5	0.3	-0.3
1970 rectangular eight-story C1	15	13	11	3.1	2.7	2.5	1.9
1970 rectangular eight-story C1 with soft story	21	19	17	1.6	1.2	1.0	0.4
1970 eight-story irregular C1 with soft story	24	22	20	1.1	0.7	0.5	-0.1
1980 rectangular eight-story C1	7	5	3	4.5	4.1	3.9	3.3
1980 rectangular eight-story C1 with soft story	13	11	9	3	2.6	2.4	1.8
1980 eight-story irregular C1 with soft story	16	14	12	2.5	2.1	1.9	1.3

Mobile Homes

Mobile homes are MH in the FEMA 154 classification scheme. Thus, the following comparison is made between the ABAG scoring system and FEMA 154 category MH. The San Jose scoring system does not address mobile homes.

Three types of mobile homes are compared. In this case, age is not an issue. Performance of mobile homes on "standard" concrete blocks or steel tripods or jacks is based on ABAG performance data from the Loma Prieta and Northridge earthquakes (Perkins and Chuaqui, 1997).

The scoring comparison is shown on Table 7 below.

TABLE 7: ABAG Scores for
Mobile Homes (Not Included in FEMA 154)

TABLE 7 NOTE – The recommendation in the ABAG scoring system is for the owner to retrofit if the score is 13 or more. Thus, for ease of comparison with other residential building types, the scores where more work is recommended are shaded.

Mobile Home Type	**ABAG Score** **Violent Shaking Exposure (MMI VIII, IX or X)**	**ABAG Score** **Strong Shaking Exposure (MMI VII)**	**ABAG Score** **Moderate Shaking Exposure (MMI VI)**
Mobile home on "standard" concrete blocks or steel tripods or jacks	**19**	**17**	**15**
Mobile home with an Engineered Tie Down System (ETS)	**12**	**10**	**8**
Mobile home with an Earthquake Resistant Bracing System (ERBS)	**11**	**9**	**7**
Mobile home on a permanent foundation	**9**	**7**	**5**

ATTACHMENT 1 - ABAG Single-Family Homes or Mobile Homes "Health" Quiz Scoring System

SCORES FOR WOOD-FRAME CONSTRUCTION (W1)

Shake Intensity	
MMI V+VI	3
MMI VII	5
MMI VIII+IX+X	7

Height/Configuration	
2 or more stories	5
Split level	6
Hillside	6
1 story w/ cripple wall	4
1 story w/o cripple wall	1

Year	
<1960	5
1961-1978	3
>1978	1

SCORES FOR MOBILE HOMES

Foundation System	
Blocks or Jacks	10
Engineered Tie Downs	5
Earthquake Resistant Bracing Systems	4
Permanent Foundation	2

ATTACHMENT 2 - ABAG Multifamily Residential Building "Health" Quiz Scoring System

Shake Intensity	
MMI V+VI	3
MMI VII	5
MMI VIII+IX+X	7

Soft Story	
All	6
Part	6
None	0

Footprint (if NOT wood)	
Box	0
L	3
T	3
U	3
O	3

Cripple Wall (if wood only)	
Yes	6
No	0

Material Choices Provided to User Based on Year/Stories Selected

	# of Stories			
Year	1	2 to 3	4 to 6	7+
<1930	W, Masonry	W, Masonry	Masonry	Masonry
1930-1945	W, Masonry	W, Masonry	C/S, Masonry	C/S, Masonry
1946-1960	W, Masonry	W, Masonry	C/S, Masonry	C/S
>1960	W, C/S, Mas.	W, C/S, Mas.	W, C/S, Mas.	C/S, Masonry

Wood

	# of Stories			
Year	1	2 to 3	4 to 6	7+
<1930	W2	W2	X	X
1930-1945	W2	W2	X	X
1946-1960	W2	W2	X	X
>1960	W2	W2	W2	X

	# of Stories			
Year	1	2 to 3	4 to 6	7+
<1930	7	10	X	X
1930-1945	7	10	X	X
1946-1960	2	5	X	X
>1960	2	5	8	X

Masonry

	# of Stories			
Year	1	2 to 3	4 to 6	7+
<1930	URM	URM	URM	URM
1930-1935	URM	URM	URM	URM
1936-1945	URM	URM	URM	URM
1946-1960	RM1	RM1	RM2	X
1961-1978	RM1	RM2	RM2	RM2
1979-2003	RM1	RM2	RM2	RM2

	# of Stories			
Year	1	2 to 3	4 to 6	7+
<1930	14	14	14	13
1930-1935	14	14	14	13
1936-1945	13	13	13	12
1946-1960	5	5	3	X
1961-1978	5	5	3	3
1979-2003	5	-4	-6	-6

Concrete and Steel (C/S)

	# of Stories			
Year	1	2 to 3	4 to 6	7+
<1930	X	X	X	X
1930-1945	X	X	S1	S1
1946-1960	X	X	C1	C1
1961-1978	C1	C1	C1	C1
1979-2003	C1	C1	C1	C1

	# of Stories			
Year	1	2 to 3	4 to 6	7+
<1930	X	X	X	X
1930-1945	X	X	6	6
1946-1960	X	X	8	8
1961-1978	8	8	8	8
1979-2003	0	0	0	0

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