ABAG Earthquake and Hazards Program

Development and Comparison of the ABAG Commercial 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 Commercial and Industrial Buildings Are At Risk

Following the completion of the residential building structural health quiz documented in ***Earthquake Internet Information Documentation Paper A*** (Perkins and Peterson, 2003), ABAG staff and members of ABAG's Earthquake Hazards Outreach Committee had several brainstorming sessions and thoughtful discussions about the advantages and disadvantages of attempting to prepare a similar quiz for commercial and industrial properties. The principal disadvantages of preparing such a quiz included:

- buildings with business uses tend to be much more diverse structurally, particularly in the variety of concrete and steel, so that the quiz would be even more general than the residential one; and
- owners of these buildings tend to have additional information on the safety of the structures that would make the quiz of minimal use.

The principal advantages of preparing such a quiz following the residential one is that the preparation time is relatively small, given that most of the technical issues had already been solved.

It was on one of the outreach meetings associated with this project that ABAG staff interviewed several building owners and determined that owners of smaller commercial buildings do not have the resources to even do a preliminary screening assessment using a structural engineer. This quiz should be of use in telling such owners when further evaluations by an engineer are warranted. In addition, the interviews made clear that there is a common myth that "if the City hasn't told me that my building has a problem, and if it did O.K. in the Loma Prieta earthquake, it will be fine in a larger or closer earthquake." This belief is not true.

As with the residential quiz, an objective in designing this quiz was to base the scoring system on questions that could be answered by a knowledgeable building owner or tenant, rather than one trained in construction or engineering.

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 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 several quizzes located on the internet related 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 – in this case, contacting a structural engineer. 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 the quizzes described earlier, in all cases the scores were in whole, not fractional, numbers.***

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 building 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, which the user self-determines by looking at several earthquake scenarios. Most of these scenarios are based on the latest U.S. Geological Survey probability report (USGS WG02, 2003) are compared. Three additional earthquake scenario maps are available, 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, provides scenario maps for these faults 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 commercial and industrial 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 building types ***except*** for the small wood-frame 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 Vertical Irregularities

Some commercial buildings have a garage, parking structure, or large display windows across 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 display windows 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 the ABAG quiz, 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. A similar penalty is imposed for story setbacks (stories of varying square footage), and for buildings on hillsides.

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

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.

Wood-frame 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 and San Jose wood-frame penalties are cumulative – that is, a wood-frame building 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 buildings are not asked this question, and are not penalized. (ABAG's approach may ***not*** be conservative for 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 buildings can include poor design, materials, workmanship, state of repair, non-code-compliant alterations, dry rot, insect damage, and settlement. 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 Buildings

Wood-frame commercial buildings can be both larger and smaller than 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 both FEMA 154 category W2 and category W1. In addition, the San Jose scoring system is also compared.

Again, a variety of buildings are compared. The 21 structures are for three age categories, two plan configurations, with and without a vertical irregularity (soft-story, story setback, or hillside construction), and three building heights (one-story, two-story, and four-story buildings). The oldest buildings are assumed 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 1 on the following page.

TABLE 1 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 building 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 buildings 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.

The scores for wood-frame buildings are identical in the ABAG quizzes for multifamily residential (W2) and commercial buildings.

TABLE 1: Approximate Relationships Among ABAG, FEMA 154, and San Jose Scores for WOOD-FRAME Buildings (FEMA Building Types W1 and W2)

Wood-Frame Residential Building Type	ABAG Score			FEMA 154 Score				San Jose Score		
	Violent Shaking Exposure	Strong Shaking Exposure	Moderate Shaking Exposure	Building Type W2 (or W1 if specified) HIGH Seismicity				Violent Shaking Exposure	Strong Shaking Exposure	Moderate Shaking Exposure
	(MMI VIII, IX or X)	(MMI VII)	(MMI VI)	Unmodified for Soil Type	Soil Type C (Dense Soil)	Soil Type D (Stiff Soil)	Soil Type E (Soft Soil)	(MMI VIII, IX or X)	(MMI VII)	(MMI VI)
1960 rectangular one-story building on a slab	9	7	5	3.8	3.4	3.0	3.0	3.6	3.9	4.2
1960 irregular one-story building on a slab	9	7	5	3.3	2.9	2.5	2.5	2.6	2.9	3.2
1960 rectangular one-story building with a cripple wall - W1	15	13	11	1.9	1.9	1.9	1.9	1.1	1.4	1.7
1960 rectangular one-story building with a cripple wall - W2	15	13	11	1.8	1.4	1.0	1.0	1.1	1.4	1.7
1960 rectangular two-story building with soft story	18	16	14	1.8	1.4	1.0	1.0	1.1	1.4	1.7
1960 irregular two-story building with soft story	18	16	14	1.3	0.9	0.5	0.5	0.1	0.4	0.7
1960 rectangular two-story building with a cripple wall - W1	18	16	14	1.9	1.9	1.9	1.9	1.1	1.4	1.7
1960 rectangular two-story building with a cripple wall - W2	18	16	14	1.8	1.4	1.0	1.0	1.1	1.4	1.7
1978 rectangular one-story building on a slab	9	7	5	6.2	5.8	5.4	5.4	3.6	3.9	4.2
1978 irregular one-story building on a slab	9	7	5	5.7	5.3	4.9	4.9	2.6	2.9	3.2
1978 rectangular two-story building on a slab	12	10	8	6.2	5.8	5.4	5.4	3.6	3.9	4.2
1978 rectangular two-story building with soft story	18	16	14	4.2	3.8	3.4	3.4	1.1	1.4	1.7
1978 irregular two-story building with soft story	18	16	14	3.7	3.3	2.9	2.9	0.1	0.4	0.7
1978 rectangular four-story building with soft story	21	19	17	4.2	3.8	3.4	3.4	1.1	1.4	1.7
1978 irregular four-story building with soft story	21	19	17	3.7	3.3	2.9	2.9	0.1	0.4	0.7
1992 rectangular one-story building on a slab	9	7	5	6.2	5.8	5.6	5.4	5.6	5.9	6.2
1992 irregular one-story building on a slab	9	7	5	5.7	5.3	5.1	4.9	4.6	4.9	5.2
1992 rectangular two-story building with soft story	18	16	14	4.2	3.8	3.6	3.4	3.1	3.4	3.7
1992 irregular two-story building with soft story	18	16	14	3.7	3.3	3.1	2.9	2.1	2.4	2.7
1992 rectangular four-story building with soft story	21	19	17	4.2	3.8	3.6	3.4	3.1	3.4	3.7
1992 irregular four-story building with soft story	21	19	17	3.7	3.3	3.1	2.9	2.1	2.4	2.7

Unreinforced Masonry Buildings

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 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 vertical irregularity (typically a building with an open front and commercial space on the ground floor, or with story setbacks), 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 2 on the following 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 scoring system is for the owner to hire a structural engineer or other design professional if the building scores below 2. Thus, for ease of comparison, the scores where contacting an engineer is recommended are shaded in Table 2.

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 reducing risks to life 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.

The scores for unreinforced masonry buildings are identical in the ABAG quizzes for residential and commercial buildings.

TABLE 2: Approximate Relationships Between ABAG and FEMA 154 Scores for UNREINFORCED MASONRY Buildings (FEMA Building Types URM, C3, and S5)

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

Reinforced Masonry Buildings

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 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 vertical irregularity (typically a building with an open front and commercial space on the ground floor, or with story setbacks), and four story heights (one-story, three-story, five-story, and eight-story buildings). Note that soft-story or other irregular 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 3 on the following 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 building scores below 2. Thus, for ease of comparison, the scores where contacting an engineer is recommended are shaded in Table 3.

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.

The scores for reinforced masonry buildings are identical in the ABAG quizzes for residential and commercial buildings.

TABLE 3: Approximate Relationships Between ABAG and FEMA 154 Scores for REINFORCED MASONRY Buildings (FEMA Building Types RM1 and RM2)

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

Concrete and Steel Buildings

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 (moment-resisting concrete frame), C2 (concrete shear wall), S1 (moment-resisting steel frame), S2 (braced steel frame), S3 (light metal), S4 (steel frame with concrete shear walls), PC1 (tilt-up concrete), and PC2 (other pre-cast concrete) designations in the FEMA 154 classification scheme. The San Jose scoring system does not apply to steel or concrete 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 4: 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 to 15**	**16 to 30**	**30+**
<1930	S1,S2,S3,S4, C1,C2	S1,S2, S4,C1,C2	S1,S2, S4,C1,C2	S1,S2, S4,C1,C2	S1,S2, S4,C1,C2	X (not applicable)
1930-1945	S1,S2,S3, C1,C2	S1,S2,S3, C1,C2	S1,S2, C1,C2	S1,S2, C1,C2	S1,S2, C1,C2	S2
1945-1960	S1,S2, C1,C2,PC1	S1,S2, C1,C2	S1,S2, C1,C2	S1,S2, C1,C2	S1,S2, C1,C2	S1,S2, C1,C2
1961-1978	S1,S2,S3,C1, C2,PC1,PC2	S1,S2,C1,C2, PC1,PC2	S1,S2,C1, C2, PC2	S1,S2,C1, C2, PC2	S1,S2,C1, C2, PC2	S1,S2, C1,C2
1979-2003	S1,S2,S3,C1, C2,PC1,PC2	S1,S2,C1,C2, PC1,PC2	S1,S2,C1, C2, PC2	S1,S2,C1, C2, PC2	S1,S2,C1, C2, PC2	S1,S2, C1,C2

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 5 on the following 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 5 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 building scores below 2. Thus, for ease of comparison, the scores where contacting an engineer is recommended are shaded in Table 5.

The ABAG system agrees with FEMA 154 in almost all cases with two notable exceptions.

The first discrepancy relates to 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, except for those constructed prior to 1930.

The second discrepancy relates to light metal buildings built prior to the mid-1970s. Because light metal buildings have been combined with all other concrete and steel buildings, owners of light metal buildings are more likely to receive scores that direct them to contact a structural engineer if they take the ABAG quiz than if they used FEMA 154. This discrepancy is felt to be acceptable because many older light metal buildings in the urban Bay Area are next to, and even share walls with, masonry and concrete buildings. They are also likely to have masonry or concrete components, in part because they are used by automotive service centers and others that have a need for fire-resistant construction.

Finally, the scores for concrete and steel buildings are NOT THE SAME in the ABAG quizzes for residential and commercial buildings. Commercial and industrial buildings are more likely to be concrete frame and tilt-ups, types of buildings that are more susceptible to problems.

TABLE 5: Approximate Relationships Between ABAG and FEMA 154 Scores for CONCRETE and STEEL Buildings (FEMA Building Types C1, C2, S1, S2, S3, S4, PC1, and PC2)

Concrete/Steel Building Type	ABAG Score			FEMA 154 Score			
	Violent Shaking Exposure (MMI VIII, IX or X)	Strong Shaking Exposure (MMI VII)	Moderate Shaking Exposure (MMI VI)	Building Types C1, S1, PC1, or PC2 - HIGH Seismicity			
				Unmodified for Soil Type	Soil Type C (Dense Soil)	Soil Type D (Stiff Soil)	Soil Type E (Soft Soil)
1930 regular one-story C2	15	13	11	1.6	1.2	1.0	0.4
1944 rectangular five-story S1	13	11	9	3.0	2.6	2.4	1.8
1944 rectangular five-story S1 with vertical irregularity	19	17	15	2.0	1.6	1.4	0.8
1944 five-story irregular S1 with vertical irregularity	22	20	18	1.5	1.1	0.9	0.3
1944 rectangular eight-story S1	15	13	11	3.4	3.0	2.8	2.2
1944 rectangular eight-story S1 with vertical irregularity	21	19	17	2.4	2.0	1.8	1.2
1944 eight-story irregular S1 with vertical irregularity	24	22	20	1.9	1.5	1.3	0.7
1935 one-story regular S3 (light metal)	15	13	11	2.6	2.2	2.0	1.6
1965 one-story regular S3 (light metal)	17	15	13	3.2	2.8	2.6	2.0
1980 one-story regular S3 (light metal)	9	7	5	3.2	2.8	2.6	2.0
1970 one-story regular PC1 (tilt-up concrete)	17	15	13	1.8	1.4	1.2	0.6
1980 one-story regular PC1 (tilt-up concrete)	9	7	5	2.6	2.2	2.0	2.2
2000 one-story regular PC1 (tilt-up concrete)	9	7	5	5.0	4.6	4.4	4.6
1970 one-story regular C1	17	15	13	2.5	2.1	1.9	1.3
1970 one-story irregular C1	20	18	16	2.0	1.6	1.4	0.8
1970 rectangular three-story C1	17	15	13	2.5	2.1	1.9	1.3
1970 rectangular three-story C1 with vertical irregularity	23	21	19	1.0	0.6	0.4	-0.2
1970 rectangular three-story irregular C1 with vertical irregularity	26	24	22	0.5	0.1	-0.1	-0.7
1970 rectangular five-story C1	17	15	13	2.9	2.5	2.3	1.7
1970 rectangular five-story C1 with vertical irregularity	23	21	19	1.4	1.0	0.8	0.2
1970 five-story irregular C1 with vertical irregularity	26	24	22	0.9	0.5	0.3	-0.3
1970 rectangular eight-story C1	17	15	13	3.1	2.7	2.5	1.9
1970 rectangular eight-story C1 with vertical irregularity	23	21	19	1.6	1.2	1.0	0.4
1970 eight-story irregular C1 with vertical irregularity	26	24	22	1.1	0.7	0.5	-0.1
1980 rectangular eight-story C1	9	7	5	4.5	4.1	3.9	3.3
1980 rectangular eight-story C1 with vertical irregularity	15	13	11	3.0	2.6	2.4	1.8
1980 eight-story irregular C1 with vertical irregularity	18	16	14	2.5	2.1	1.9	1.3

ATTACHMENT 1 - ABAG Commercial Building "Health" Quiz Scoring System

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

Vertical Irregularity	
Open/Soft-Story	6
Story Setbacks	6
Hillside Setbacks	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 to 15	16 to 30	30+
<1930	W, C/S, Mas.	W, C/S, Mas.	C/S, Masonry	C/S, Masonry	C/S, Masonry	X (error message)
1930-1945	W, C/S, Mas.	W, C/S, Mas.	C/S, Masonry	C/S, Masonry	C/S, Masonry	C/S, Masonry
1946-1960	W, C/S, Mas.	W, C/S, Mas.	C/S, Masonry	C/S	C/S	C/S
>1960	W, C/S, Mas.	W, C/S, Mas.	W, C/S, Mas.	C/S, Masonry	C/S	C/S

Wood

	# of Stories					
Year	1	2 to 3	4 to 6	7 to 15	16 to 30	30+
<1930	W2	W2	X	X	X	X
1930-1945	W2	W2	X	X	X	X
1946-1960	W2	W2	X	X	X	X
>1960	W2	W2	W2	X	X	X

	# of Stories					
Year	1	2 to 3	4 to 6	7 to 15	16 to 30	30+
<1930	7	10	X	X	X	X
1930-1945	7	10	X	X	X	X
1946-1960	2	5	X	X	X	X
>1960	2	5	8	X	X	X

Masonry

	# of Stories					
Year	1	2 to 3	4 to 6	7 to 15	16 to 30	30+
<1930	URM	URM	URM	URM	URM	X
1930-1935	URM	URM	URM	URM	URM	URM
1936-1945	URM	URM	URM	URM	URM	URM
1946-1960	RM1	RM1	RM2	X	X	X
1961-1978	RM1	RM2	RM2	RM2	X	X
1979-2003	RM1	RM2	RM2	RM2	X	X

	# of Stories					
Year	1	2 to 3	4 to 6	7 to 15	16 to 30	30+
<1930	14	14	14	13	13	X
1930-1935	14	14	14	13	13	13
1936-1945	13	13	13	12	12	12
1946-1960	5	5	3	X	X	X
1961-1978	5	5	3	3	X	X
1979-2003	5	-4	-6	-6	X	X

Concrete and Steel (C/S)

	# of Stories					
Year	1	2 to 3	4 to 6	7 to 15	16 to 30	30+
<1930	S1,S2,S3,S4,C1,C2	S1,S2, S4,C1,C2	S1,S2, S4,C1,C2	S1,S2, S4,C1,C2	S1,S2, S4,C1,C2	X
1930-1945	S1,S2,S3, C1,C2	S1,S2,S3, C1,C2	S1,S2,C1,C2	S1,S2,C1,C2	S1,S2,C1,C2	S2
1946-1960	S1,S2, C1,C2,PC1	S1,S2,C1,C2	S1,S2,C1,C2	S1,S2,C1,C2	S1,S2,C1,C2	S1,S2,C1,C2
1961-1978	S1,S2,S3,C1,C2,PC1,PC2	S1,S2,C1,C2, PC1,PC2	S1, S2, C1, C2, PC2	S1, S2, C1, C2, PC2	S1, S2, C1, C2, PC2	S1,S2,C1,C2
1979-2003	S1,S2,S3,C1,C2,PC1,PC2	S1,S2,C1,C2, PC1,PC2	S1,S2,C1,C2, PC2	S1,S2,C1,C2, PC2	S1,S2,C1,C2, PC2	S1,S2,C1,C2

	# of Stories					
Year	1	2 to 3	4 to 6	7 to 15	16 to 30	30+
<1930	12	12	10	9	9	X
1930-1945	8	8	6	6	6	6
1946-1960	8	8	6	8	8	8
1961-1978	10	10	10	10	10	10
1979-2003	2	2	2	2	2	2

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