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VULNERABILITY OF RC FRAME STRUCTURES IN TURKISH EARTHQUAKE REGIONS (PART 1): INSTRUMENTAL TESTING

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SUMMARY

The present paper describes the experimental identification of dynamic building characteristics conducted on selected RC frame structures in Turkish earthquake regions. In addition to identifying the building's structural parameters, such as natural building frequencies, f_n, or damping coefficients, ξ, experimental investigations of the building sites were performed to derive the predominant site frequencies, f_s.

Investigation results can be applied to survey possible influences of site effects, i.e. resonance phenomena between site and structure during earthquake action, on the amount of structural damage. They also establish a basis from which reliable structural models can be realized and from which alternative seismic loads representative for the given site and subsoil conditions can be provided.
Modeling and dynamic structural analysis of the investigated buildings is presented in the second part of the paper (Part 2: Abrahamczyk et al. [1]).

INTRODUCTION

Since 1992 field missions of the reconnaissance teams of German TaskForce for Earthquakes were carried out in Turkish earthquake regions. Especially the field studies after the earthquakes in 1998 Adana/Ceyhan, 1999 İzmit (Kocaeli) and Duezce (Bolu), and 2002 Sultandağı (Afyon) provided a comprehensive database of instrumental ground motion records and information on structural damage.

In order to supplement recorded ground motion data (aftershock recordings) and to enable an advanced interpretation of structural damage, additional field missions to the earthquake-affected provinces were performed by the engineering group of German TaskForce in October 2000 and September 2002.
The main objective of the field-trip in September 2002 into different Turkish provinces was to instrumentally investigate multistoried RC frame structures and their sites.

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STRATEGY AND OBJECTIVE

The experimental investigations performed during the Post-TaskForce mission in September 2002 were concentrated on nine selected buildings (Figure 1) situated in Aegean and Northanatolian provinces of Turkey. All buildings are principally characterized by having multistoried (3- to 7-stories), reinforced-concrete frames, which represent the primary supporting structure. Most of the structures are furnished with masonry infills over all stories, while infills on the ground level are sometimes missing. The construction status of three of the buildings can be described as purely RC frame skeletons, since no infills were attached to the structure at the time of the damaging earthquake (cf. Table 1).

The following are reasons for selecting this type of structural system:

- the high vulnerability to dynamic loads leading to high damage concentrations,
- its prevalence within the respective earthquake areas,
- the possibility of analyzing buildings having (nearly) similar layout shapes, but different numbers of stories,
- the possibility of analyzing uniform buildings located at different sites with different subsoil conditions.

In order to ensure a reliable analysis of structural vulnerability as a result of dynamic earthquake impact experimental investigations were carried out not only on the structure but also on the site.

Table 1. General information on investigated RC frame structures.

Structure	Index	Year of constr.	Structural characteristics [1]				Damaging mainshock	Damage grade *DG* [3]
			N [2]	Base-ment	Brick infills	Peculiarities		
İzmit 1	IZT-1	1999	7	○	○	without brick infills	1999 İzmit	3
İzmit 2a	IZT-2a	1999	6	○	○	without brick infills	1999 İzmit	3
İzmit 2b	IZT-2b	1999	6	○	◐	soft ground story	1999 İzmit	3
İzmit 2c	IZT-2c	2002	4	○	◐	soft ground story	-	-
Düzce 1	DUZ-1	1999	4 (5)	●	●	-	1999 İzmit and Düzce	0
Düzce 2	DUZ-2	1995/96	5 (6)	●	●	-	1999 İzmit and Düzce	2-3
Sapança	SAC	2002	3	○	◐	soft ground story	-	-
Seymen	SEY	< 1995	4	○	●	-	1999 İzmit	2
Sultandağı	SUL	2001/02	5	○	○	without brick infills	2002 Sultandağı	3

1) ● present ◐ partly present ○ not present
2) parantheses indicate the total story number, *N*, including basements
3) grade of damage according to the European Macroseismic Scale EMS-1998 (Grünthal (ed.) et al. [2])

(a) *Sultandağı SUL* (b) *Sapanca SAC* (c) *İzmit IZT-1*

(d) *İzmit IZT-2a* (e) *İzmit IZT-2b* (f) *İzmit IZT-2c*

(g) *Seymen SEM* (h) *Düzce DUZ-1* (j) *Düzce DUZ-2*

Figure 1. Views of the nine experimentally investigated structures in (a) Aegean and (b)-(j) Northanatolian provinces of Turkey.

IDENTIFICATION OF DYNAMIC BUILDING CHARACTERISTICS

Instrumentation of the structure

The most reliable method of structural modeling is found in the experimental identification of the dynamic characteristics of the existing building (Lang [3]).

The instrumentation of the selected buildings (Table 1, Figure 1) was realized by the use of a multichannel-acquisition system and several high-sensitive seismic sensors distributed at different stories and layout positions of the building. The multichannel-analyzer of type YOKOGAWA DL-716 ensures the simultaneous recording of the building's dynamic response by a maximum number of five triaxial seismic sensors. Figure 2 illustrates the instrumentation of a building schematically.

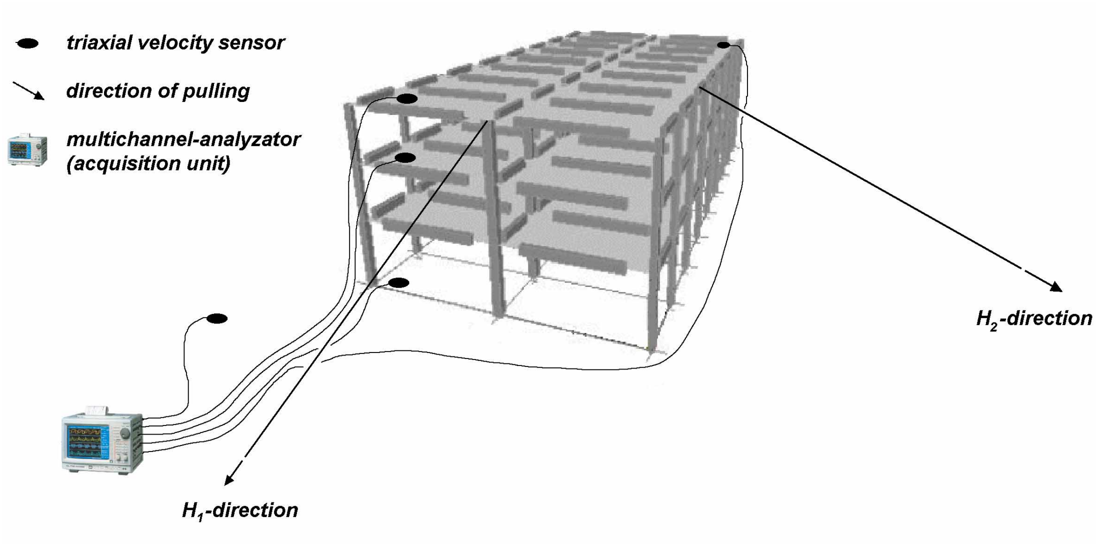


Figure 2. Instrumentation scheme for the experimental identification of the dynamic response characteristics and for the principle of rope pulling in both horizontal building axes (H_1, H_2).

In addition to four seismic velocity sensors placed within the building, a reference sensor is installed on the outside in order to clearly identify interspersing signals not coming from the structure itself. Sensors were placed in opposite corners of the building to clearly identify even torsional mode shapes going around the building's vertical axis.

Types of dynamic excitation

To excite the building, not only is ambient noise mainly coming from wind and environmental disturbances applied, but also a type of external excitation. The latter consists of people pulling the structure by a rope fixed at a primary structural element (e.g. outer column or beam) from the outside (cf. Figure 3). As illustrated in Figure 2, the external excitation was applied to the structure in both principal building axes.

It should be stated that this type of external excitation method is restricted by the building's stiffness, and thus by its number of stories and principal structural system. Since this type of excitation is achieved by manpower, its applicability to very stiff structures, i.e. those with less than three stories or furnished by rigid masonry infill walls, is not promising.

Analysis of instrumental data

With regard to Figure 4 the necessity of having a strong, distinct excitation becomes clear. Compared with noise excitation, Figure 4 demonstrates that this technique allows a more reliable identification of the distinct natural building frequencies, f_n, and thus of their respective mode shapes. By using this type of excitation, even structural damping factors, ξ, ideally can be determined.

Table 2 summarizes the main results of the instrumental measurements carried out at the nine selected structures. Figure 5 correlates the experimentally identified fundamental periods, $T_{n,exp}$, with the number of stories, N. These are overlaid by curves of empirical formulas to calculate the fundamental frequencies of RC frame structures as specified in international building codes (e.g. of Turkey, the United States) or other publications (e.g. Bayülke [4]). Empirical relationships based solely on the story number, N, clearly cannot estimate the fundamental period, T_n, of the assortment of buildings analyzed here. Since the general dimensions of the building, such as its total height, h_n, or its overall length, L, in the direction under consideration, have strong influences on the dynamic shaking characteristics, Table 3 displays the experimental values of the fundamental periods, $T_{n,exp}$, with those calculated by more specified formulas as collected by Goel & Chopra [5], Hampe [6], and Hampe et al. [7].

Figure 3. External excitation of the building from the outside produced by manpower.

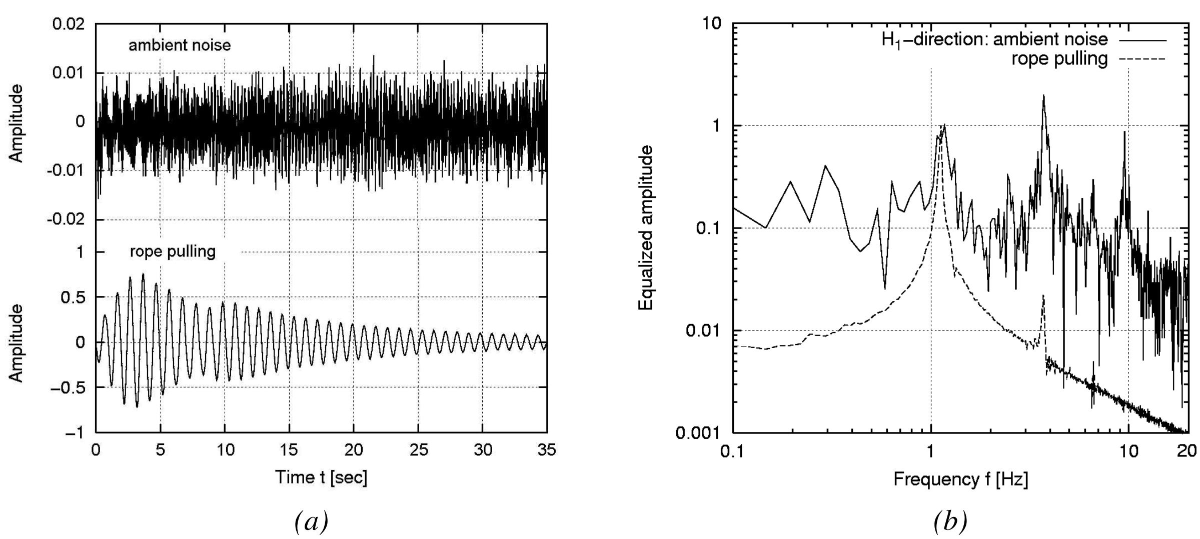


Figure 4. Differences between the structural response excited by ambient noise and rope pulling in (a) the time domain, and (b) the frequency domain.

Table 2. Main results of the dynamic measurements at RC frame structures for both major building axes.

Index	No. of stories [1)]	Brick infills [2)]	First mode period, $T_{n,exp}$ [sec]		Damping factor, ξ [%]		Damage grade DG [3)]
			H_1-direction	H_2-direction	H_1-direction	H_2-direction	
IZT-1	7	○	0.68	0.69	6.30	8.10	3
IZT-2a	6	○	0.85	0.66	6.60	6.80	3
IZT-2b	6	◐	0.50	0.73	7.90	8.50	3
IZT-2c	4	◐	0.21	0.23	-	-	-
DUZ-1	4 (5)	●	0.26	0.29	-	-	0
DUZ-2	5 (6)	●	0.47	0.73	-	-	2-3
SAC	3	◐	0.15	0.20	-	-	-
SEM	4	●	0.33	0.40	-	-	2
SUL	5	○	0.89	0.71	6.5	6.9	3

1) brackets indicate the total number of stories, *N*, including basements
2) ● present ◐ partly present ○ not present
3) grade of damage according to the European Macroseismic Scale EMS-1998 (Grünthal (ed.) et al. [2])

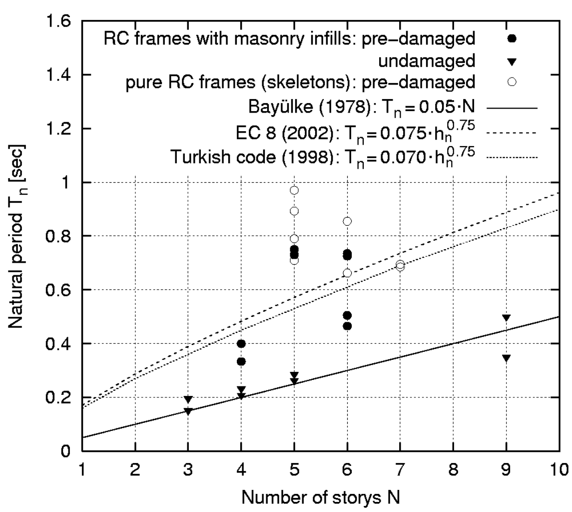


Figure 5. Comparison between experimentally identified fundamental periods, $T_{n,exp}$, and empirical formulas specified in different building codes.

The investigation results given in Table 3 illustrate that empirical formulas incorporating the structures' principal dimensions are apparently more suitable to meet the experimentally identified fundamental periods of the structures, $T_{n,exp}$. Given that no experimental data on buildings is available, these results are of the greatest interest for at least estimating the natural building periods, T_n.

In addition, results presented in Table 3 cannot confirm the large differences between the experimental periods, $T_{n,exp}$, for undamaged and pre-damaged structures, as seen in Figure 5. Discrepancies between the experimental and empirical fundamental periods, T_n, of an individual structure may be explained by structural peculiarities (e.g. unusually high overall stiffness due to the presence of single shear-walls or low overall stiffness due to extremely bad concrete quality) rather than by pre-damaging effects, which can possibly lead to an enlargement of the fundamental period by a significant decrease in stiffness.

Nevertheless, this should be taken into account along with the calibration procedure of the theoretical structural model (cf. Part 2: Abrahamczyk et al. [1]) in cases where moderate damages to primary structural elements occur.

Besides the experimental identification of natural building periods, T_n, and their reflection on empirical relationships, the estimation of the single mode shapes is of great interest with regard to the modeling procedure and further structural analysis.

Table 3. Comparison between experimental and calculated fundamental periods, T_n, of buildings investigated using more accurate empirical formula relationships.

Index	N [1)]	Direction	Total height, h_n [m]	Length in direction, L [m]	Experim. identified period, $T_{n,exp}$ [sec] [2)]	Period T_n acc. to empirical relationships [2)]		
						ICBO [8]	ATC [9] with infills	no infills
						$T_n = 0.09 \cdot N \cdot \sqrt{\frac{h_n}{L}}$	$T_n = 0.09 \cdot \frac{h_n}{\sqrt{L}}$	$T_n = 0.1 \cdot N$
IZT-1	7	H_1	19.60	20.25	**0.68**	0.62	-	0.70
		H_2		13.15	**0.69**	0.77	-	
IZT-2a	6	H_1	16.90	19.00	***0.85***	*0.51*	-	0.60
		H_2		19.80	**0.66**	0.50	-	
IZT-2b	6	H_1	16.90	19.00	**0.50**	0.51	0.35	-
		H_2		19.80	***0.73***	*0.50*	*0.34*	-
IZT-2c	4	H_1	11.30	18.90	**0.21**	0.28	0.23	-
		H_2		19.75	**0.23**	0.27	0.23	-
DUZ-1	4	H_1	11.40	18.00	**0.26**	0.29	0.24	-
		H_2		12.63	**0.29**	0.34	0.29	-
DUZ-2	5	H_1	17.15	11.65	**0.47**	0.55	0.45	-
		H_2		14.45	**0.73**	0.49	0.41	-
SAC	3	H_1	8.70	10.55	**0.15**	0.25	0.24	-
		H_2		9.40	**0.20**	0.26	0.26	-
SEM	4	H_1	12.20	12.50	**0.33**	0.36	0.31	-
		H_2		9.70	**0.40**	0.40	0.35	-
SUL	5	H_1	15.50	15.53	***0.89***	*0.45*	-	*0.50*
		H_2		15.35	***0.71***	*0.45*	-	

1) number of stories, N, excluding basements
2) low consistencies between experimental and calculated periods are *italicized*

IDENTIFICATION OF THE LOCAL SITE CHARACTERISTICS

In order to allow a detailed and integrated analysis of structural earthquake damage, the identification of local site characteristics is of the greatest importance. Based on this information, a reliable categorization of the site and subsoil conditions should be realized in order to provide reliable seismic loads for further structural analysis.

In general, site categorization depends on geotechnical information on the different soil materials and subsoil stratigraphy. This in turn assumes that data be obtained by geotechnical (boreholes) or seismic exploration methods (surface reflection/refraction), which are usually time- and cost-consuming.

An alternative to the conventional methods of site investigation can be found in using hybrid procedures as recently proposed by Bray & Rodríguez-Marek [10] and Lang [3], to name a few. By applying the spectral H/V-method on microtremor data recorded at the ground surface of the respective site, for example, information on the local subsoil conditions can be deduced (cf. Lang [3], Lang et al. [11]).

Spectral H/V-method on microtremors

Since spectral H/V-ratios on microtremors (*HVNR*) represent the "quasi"-transfer function of the local subsoil profile, an initial estimate on the soil stiffness and thickness of sedimentary layers can be made. As is generally accepted, spectral H/V-ratios can be used to identify the predominant site period, T_s, and a qualitative estimate of local site amplification. Figure 6 illustrates the spectral H/V-ratios on microtremors for two sites of damage cases that will be addressed in part 2 of this paper (Abrahamczyk et al. [1]).

Microtremor recordings were performed directly at the sites of each of the analyzed buildings. Influencing effects coming from surface topography and thus possibly altering the site response characteristics can be excluded as all buildings were situated on flat terrain.
The seismic free-field records were realized by RefTek acquisition units and triaxial seismometers of type Lennartz LE-3D/5sec (velocity-type).

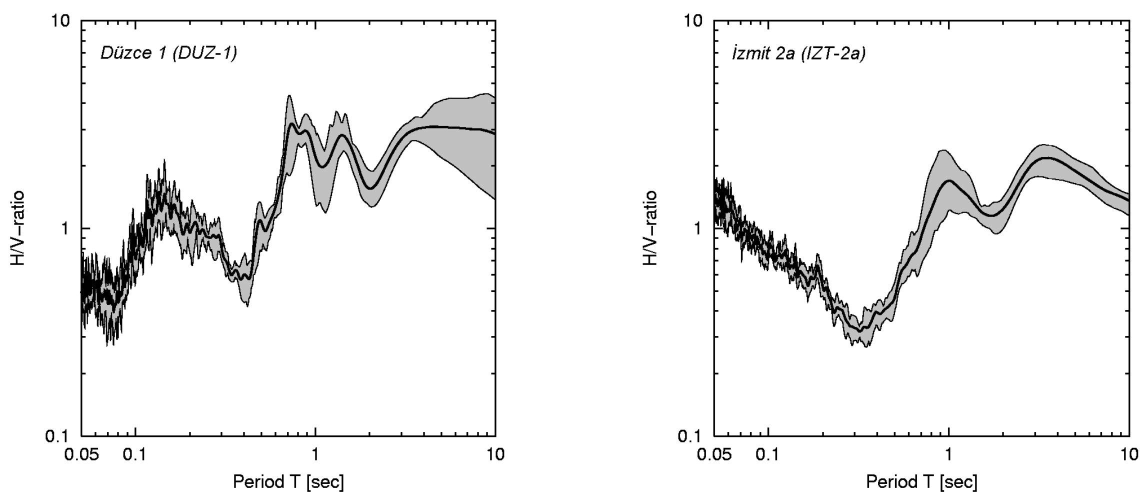


Figure 6. Spectral H/V-ratios on microtremors at particular building sites. (Bold lines indicate the mean value of several H/V-ratios for successive time segments, and gray-shaded areas are limited by the mean value +/- standard deviation.)

Damage contribution of site effects

Once the spectral H/V-ratios on microtremors (*HVNR*) are calculated and predominant site periods, T_s, are determined, a comparison with natural building periods, $T_{n,exp}$, can be conducted (cf. Table 4, Figure 7). This allows for an examination as to whether resonance effects between site and structure contributed to the structural damages. Resonance phenomena, which are also denoted as seismic site effects, are quite often used for damage interpretation in order to divert from structural deficiencies.

Results given in Table 4 and Figure 7 indicate that resonance effects between the site and the structure of damage cases discussed here may not have contributed to the extent of structural damage. No clear agreement between the experimentally identified natural building periods, $T_{n,exp}$, and (first) predominant site periods, $T_{s,i}$, can be observed in any of the damage cases.

Table 4. Comparison of natural building periods, $T_{n,exp}$, and predominant site periods, $T_{s,i}$, for instrumentally investigated damage cases in Turkey.

Index	Natural building period, $T_{n,exp}$ [sec]		Predominant site periods, $T_{s,i}$ [sec] (on the basis of *HVNR*)			Concurrence 1) between $T_{n,exp}$ and $T_{s,i}$
	H_1-direction	H_2-direction	1st peak	2nd peak	3rd peak	
IZT-1	*0.68*	*0.69*	2.5 - 5.0	1.0 - 1.1	*0.67*	◐ 3rd peak of *HVNR*
IZT-2a	0.85	0.66	3.3 - 4.0	1.0 - 1.25	-	○
IZT-2b	0.50	0.73	3.3 - 4.0	1.0 - 1.25	-	○
IZT-2c	0.21	0.23	3.3 - 4.0	1.0 - 1.25	-	○
DUZ-1	0.26	0.29	1.25 - 1.7	0.67 - 1.0	-	○
DUZ-2	0.47	*0.73*	1.1 - 1.4	*0.6 - 0.7*	-	◐ 2nd peak of *HVNR*
SAC	0.15	0.20	0.9 - 1.25	-	-	○
SEM	0.33	0.40	0.9 - 1.4	-	-	○
SUL	0.89	0.71	0.4 - 0.5	0.2 - 0.25	-	○

1) ● high ◐ restricted ○ no

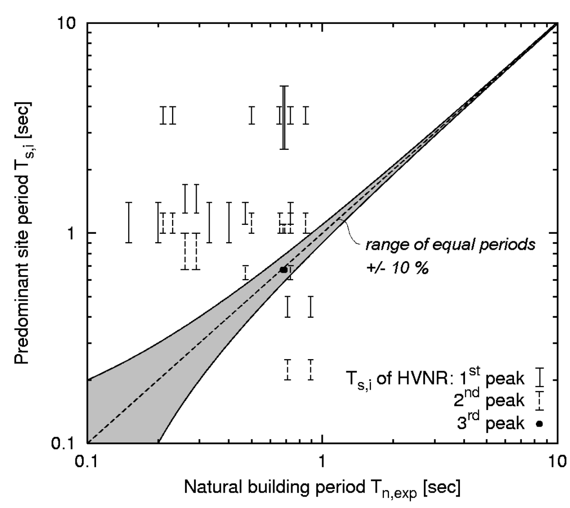


Figure 7. Graphic illustration of natural building periods, $T_{n,exp}$, and predominant site periods, $T_{s,i}$, at the instrumentally investigated damage cases. (The dashed line indicates equal periods, $T_{n,exp} = T_{s,i}$. The gray-shaded area represents +/- 10% variation.)

Concept of site classification

As already stated above, a reliable classification of the site can be regarded as indispensable for allowing a capacious structural analysis. A variety of site classification schemes are usually incorporated in different international earthquake codes (Lang et al. [11]).

In contrast to conventional classification schemes, which usually depend on detailed geotechnical information on the soil materials, alternative methods of site categorization exist. The latter is based on the results of instrumental seismic site investigations rather than on the geotechnical data from boreholes or seismic exploration methods. So-called "hybrid classification schemes" recently have been presented by Bray & Rodríguez-Marek [10] and Lang [3]. The latter introduces a classification concept within the framework of the "*M*ethod of an *E*xperimental *S*eismic *Si*te *As*sessment (*MESSIAS*)."

Both concepts are based principally on available code classification schemes. Bray & Rodríguez-Marek [10] primarily use predominant site period, T_s, to subdivide the 1997-UBC (ICBO [8]) site classes according to their total sediment thicknesses. Since the classification scheme of the 1997-UBC was originally only related to the uppermost 100 ft (30 m) of the soil profile, a more refined classification based on this scheme can be achieved for the whole soil profile down to geological bedrock.

On the other hand, the site classification procedure as proposed by Lang [3] makes use of the different "site-specific" subsoil classes following the German earthquake code DIN 4149 (DIN [12]). Here a twofold classification is carried out that distinguishes between the type or consistency of soil materials of the uppermost layers (25 m) and the extent of sedimentary materials. Soil material types are represented by three different soil condition classes (1, 2, and 3), which basically differ in average shear-wave velocity, v_s. In addition, geological subsoil classes (A, B, and C) take the geological subsurface conditions into account, and thus stand for the total thickness of overlying sediments. As Figure 8 illustrates, only six respectively seven combinations between soil condition classes and geological subsoil classes into so-called "site-specific subsoil classes (SC)" are possible. In this context it should be stated that Schwarz et al. [13] proposed a subdivision into seven different site-specific subsoil classes that complements class C2.

The intrinsic procedure of site classification described by Lang [3] rests mainly on the conformity between the experimentally determined quasi-transfer function, TF_{quasi}, and the theoretical transfer function, TF_{theo}, of an idealized subsoil profile which is compatible to one of the different site-specific subsoil classes (SC). Spectral H/V-ratios on microtremors recorded at the ground surface are considered to represent the quasi-transfer function of the subsoil profile. The spectral H/V-ratios of Figure 6 confirm that their spectral peaks point to predominant site periods, $T_{s,i}$.

Since each of the site-specific subsoil classes can be described by 1) a variety of model profiles covering the upper and lower bound of soil material stiffness (in terms of shear-wave velocity, v_s), and 2) total sedimentary thickness, H, their respective theoretical transfer functions, TF_{theo}, describe a certain spectral range of predominant site periods. Consequently, a classification of the site can be achieved by comparing its predominant site period taken from the spectral H/V-ratios on microtremors (*HVNR*) with ranges of theoretically determined site periods of corresponding model profiles. A more detailed description of this classification procedure is given by Lang [3] and Lang et al. [11].

Even though this hybrid method of site classification was developed based on the site-specific subsoil classes of the German earthquake code DIN 4149 [12], it can certainly be adopted to any classification scheme. With respect to the structural analysis of the damage cases presented here, applying this procedure to the site classes of the Turkish earthquake code (TMPS [14]) may be reasonable. As Figure 9 illustrates, the classification scheme of the Turkish code is based on the definition of four different soil groups (A)-(D). A further arrangement of soil groups put into local site classes Z1-Z4 dependent on the total thickness of sedimentary layers, *h*, has also been achieved.

Using spectral H/V-ratios on microtremors as a starting point, a site classification of the different damage cases can be conducted. Table 5 specifies the allocated site (subsoil) classes according to classification schemes of Bray & Rodríguez-Marek [10], the German (DIN 4149 [12]), and the Turkish earthquake code (TMPS [14]).
The sophisticated 1997-UBC classification scheme by Bray & Rodríguez-Marek [10] does not have any influence on the shape of elastic design spectra.
In Figure 10 normalized elastic design spectra of the German and Turkish earthquake codes are depicted. As it can be taken from part 2 of this paper (cf. Abrahamczyk et al. [1]) elastic design spectra of both earthquake codes establish a main basis for further structural analyses.

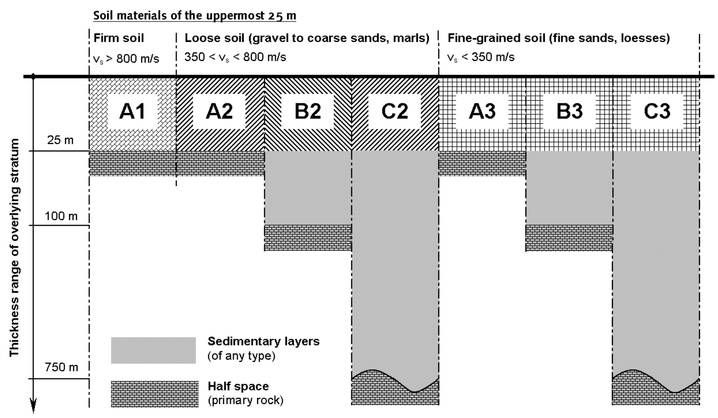


Figure 8. Possible combinations of site-specific subsoil classes (SC) according to the German earthquake code DIN 4149 (DIN [12]).

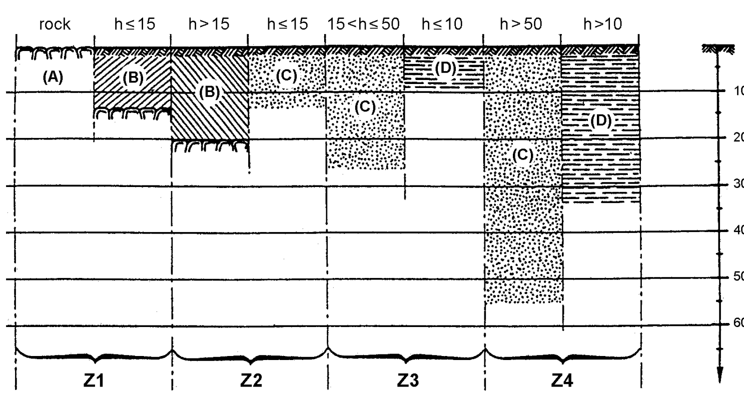
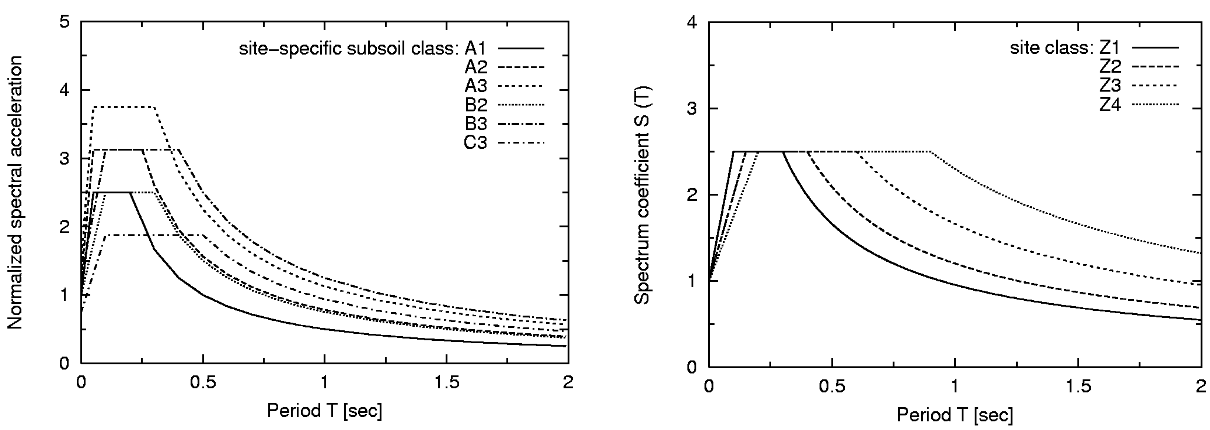


Figure 9. Soil groups arranged into local site classes as defined in the Turkish earthquake code regulation (TMPS, 1998). (Modified figure taken from AFPS [15].)

Table 5. Classification of the sites of investigated damage cases according to different classification schemes.

Index	Bray & Rodríguez-Marek [10] [1)]	German code DIN 4149 [12]	Turkish code TMPS [14]
IZT-1	D-3	C3	Z4
IZT-2a [2)]	D-3	C3	Z4
IZT-2b	D-3	C3	Z4
IZT-2c	D-3	C3	Z4
DUZ-1 [2)]	D-1	B3	Z3-Z4
DUZ-2	D-1	B3	Z3-Z4
SAC	C-3	B2	Z2
SEM	D-1	B3	Z4
SUL	C-2	A2-B2	Z2

1) sophisticated site classes of the 1997-UBC (ICBO [8]) in dependence on predominant site period, T_s
2) detailed investigations of these damage cases are presented in part 2 of this paper (Abrahamczyk et al. [1])



(a) German code *(b) Turkish code*

Figure 10. Normalized elastic response spectra for site classes of (a) the German (DIN 4149 [12]) and (b) the Turkish earthquake code regulation (TMPS, 1998).

CONCLUSIONS

The instrumental investigations presented in this paper on both the structure and the site of selected damage cases in Turkish earthquake regions were designed to elaborate on necessary input parameters, enabling a reliable analysis of structural earthquake damage.

The instrumental investigations on selected RC frame structures can be valued as a suitable tool to experimentally identify natural building periods, $T_{n,exp}$, their respective mode shapes, and in some cases even structural damping coefficients, ξ.

This provides a good opportunity to calibrate the structural models to their modal analysis results, and thus to develop more reliable building models. Pre-damaging effects of previous earthquake shaking are thereby incorporated, providing significant information on the structural vulnerability.
A more detailed description of the calibration procedure will be given in part 2 of this paper (Abrahamczyk et al. [1]).

In contrast to the instrumental investigations of the structure, those of the site are also of greatest interest for allowing an integrated structural analysis. In doing so, spectral H/V-ratios on microtremor data (*HVNR*) recorded at the ground surface establish a solid basis from which to proceed.
In addition to the rapid determination of predominant site periods, T_s, which allows the survey of site effects possibly contributing to the extent of structural damage, the hybrid site classification presented here as a part of the *MESSIAS* procedure (Lang [3], Lang et al. [11]) provides a variety of advantages:

- an estimation of the total thickness of overlying sedimentary soil layers, and thus a more realistic classification of the site,
- an evaluation of "surrogate" subsoil profiles (if no data on the subsoil stratigraphy is present), or verification of available subsoil information,
- a warranty of comparable results, since spectral H/V-ratios on microtremors can be easily obtained at any site.

As comprehensively demonstrated by Lang [3], the application of experimental site estimations and connected hybrid site classification based on customary schemes (e.g. as provided in earthquake codes) within an engineering analysis of structural damage may help to perform the following:

- to select suitable mainshock data of (neighboring) recording sites that have comparable subsoil conditions to the site of interest,
- to select alternative weak-motion records (e.g. aftershocks) at the site that represent the frequency characteristics of the damaging mainshock, and which are thus applicable for extrapolation to higher levels of ground acceleration,
- to provide shapes of site-dependent elastic design spectra (e.g. of the current earthquake code) that represent the theoretical response characteristics of the site during earthquakes,
- to provide shapes of predicted response spectra on the basis of subsoil-dependent attenuation relationships for both peak ground acceleration, *PGA*, and spectral accelerations, S_a; results for simplified site classes were recently published by Schwarz et al. [16].

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REFERENCES

1. Abrahamczyk L, Schott C, Swain TM, Schwarz J. “Vulnerability of RC frame structures in Turkish earthquake regions (Part 2): Modeling and analysis.” Proceedings of the 13th World Conference on Earthquake Engineering, Vancouver, Canada, 2004. Paper no. 220.
2. Grünthal G (ed.), Musson R, Schwarz J, Stucchi M. “European Macroseismic Scale 1998.” Cahiers du Centre Européen de Geodynamique et de Séismologie; Volume 15, Luxembourg, 1998.
3. Lang DH. “Damage potential of seismic ground motion considering local site effects.” Ph.D. thesis, Earthquake Damage Analysis Center, Institute of Structural Engineering, Bauhaus-University Weimar, February 2004: 297 pp.
4. Bayülke N. “Tuğla yığma yapıların depremlerdeki davranışı.” Deprem Araştrıma Enstitüsü Bülteni 1978; 6(22): 26-41.
5. Goel RK, Chopra AK. “Evaluation of code formulas for fundamental period of buildings.” Proceedings of the 11th World Conference on Earthquake Engineering, Acapulco, Mexico. Paper no. 1127.
6. Hampe E. “Bauwerke unter seismischen Einwirkungen, Teil 2. Studienmaterial des Instituts für Aus- und Weiterbildung im Bauwesen.” 1. Auflage; Leipzig, 1985.
7. Hampe E, Goldbach R, Schwarz J. “Verhalten von Bauwerken unter seismischen Einwirkungen.” Bautechnik 1991; 68(7).
8. International Conference of Building Officials (ICBO): “1997 Uniform Building Code (1997-UBC).” Whittier/CA, United States of America, 1997: 492 pp.
9. Applied Technology Council (ATC): "Tentative Provisions for the Development of Seismic Regulations for Buildings, Report No. ATC3.06". 1978.
10. Bray JD, Rodríguez-Marek A. “Geotechnical site categories.” Proceedings of the 1st PEER-PG&E Workshop on Seismic Reliability of Utility Lifelines 1997, San Francisco, California.
11. Lang DH, Schwarz J, Ende C. “Subsoil classification of strong-motion recording sites in Turkish earthquake regions.” Schriftenreihe der Bauhaus-Universität Weimar 2004; 116: 12 pp.
12. Deutsches Institut für Normung (DIN). “DIN 4149, Bauten in deutschen Erdbebengebieten.” Berlin, 2002.
13. Schwarz J, Lang DH, Golbs C. “Erarbeitung von Spektren für die DIN 4149-neu unter Berücksichtigung der Besonderheiten deutscher Erdbebengebiete und der Periodenlage von Mauerwerksbauten.” Scientific report on behalf of the “Deutschen Gesellschaft für Mauerwerksbau e.V.” Earthquake Damage Analysis Center, Bauhaus-University Weimar, September 1999.
14. Turkish Ministry of Public Works and Settlement (TMPS). “Specification for Structures to be built in Disaster Areas. Part III – Earthquake Disaster Prevention (Chapter 5-13).” Effective from 1.1.1998. English translation, 1998: 84 pp.
15. Association Francaise du Genie Parasismique (AFPS). “Recommendations AFPS-90 pour la redaction des regles relatives aux ouvrages et installations a realiser dans les regions sujettes aux seismes.” Presse des Ponts et Chaussées 1990, Paris, France.
16. Schwarz J, Ende C, Habenberger J, Lang DH. “Site-dependent spectra from the 1999 Turkey earthquakes considering different sets of strong-motion data.” Poster presentation. EGS-AGU-ESC Joint Assembly 2003, Nice, France.