Preliminary aspects on ground motion, site characterization and structural damage of Durrës earthquake (Mw6.4, 26-11-2019)

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1 INTRODUCTION

On November 26, 2019 at 02:54 GMT a strong earthquake of magnitude M6.4 (thrust-type fault mechanism), occurred in Adriatic Sea close to the City of Durrës in Albania. The coordinates of the epicentral area were 41.38°N and 19.47°E and the focal depth of almost 10 km, strongly affected the most populated areas of Durrës and Tirana, as well as the adjacent regions. The earthquake was strongly felt in an extensive part of NW area of Greece (Epirus), same as, in North Macedonia, Montenegro, Kosovo and Italy.

In order to better understand and evaluate the seismic performance of structures, the seismic demand should be compared to the current seismic code provisions and the observed damage of structures should be related to the expected damage. Therefore, the present study focuses on the comparison of the seismic demand to the provisions of Albanian seismic code (KTP-N.2-89) and Eurocode (EC8), in terms of spectral values and available ductility and ductility demand. To this end, the preliminary seismological information and the near-field strong motion recorded at the Durrës accelerometric station (Duni and Theodoulidis, 2020) are used and earthquake ground motions from widely used worldwide databases are collected. Response spectra of the recorded motion, the selected motions from databases and the synthetic accelerograms are produced and compared to the design spectra prescribed in current code provisions, both in Albanian seismic code (KTP-N.2-89) and Eurocode (EC8). Assumptions regarding the soil type are based on the V_{s30} values and both elastic and inelastic response spectra are produced and compared. The available ductility is calculated based on code spectral values and is related to the damage observed in Durrës and Thumanë area during a recent field mission, as a preliminary step to evaluate seismic performance of existing structures and propose measures and actions to ensure damage mitigation in future events.

2 EARTHQUAKE GROUND MOTION

Information regarding the strong seismic motion recorded at the Durrës accelerometric station is available in Duni and Theodoulidis(2020) and the elastic response spectra of the NS and EW component are presented in Fig.1.

Based on the earthquake characteristics reported by IGEWE and EMSC, an effort was made to collect strong motion recordings originating from similar seismic regimes at stations with similar soil conditions to the region studied herein (Durrës station). Therefore, records were selected from ESM (https://esm.mi.ingv.it/)&ITACA (http://itaca.mi.ingv.it/) databases and are presented in Table 1. Regarding the selection criteria, the earthquake characteristics (M_w, R_{epi} from DURR station) were considered, along with criteria involving the PGA values which were not intended to deviate significantly from the reported values at DURR station.

Table 1. Accelerograms selected from ESM and ITAKA databases

A/A	Date	Origin Time	Lat	Lon	M	Dep	Repi	Rjb	Rrup	Azim	Stn-Code	ITACA-ID	pga_E	pga_N	pga-Z
1	15-09-76	3:15:18	46.285	13.203	6	6.8	11.2	6.3	6.56	51	BUI	IT-1976-0027	-91.341	108.4962	68.2487
2	15-09-76	9:21:18	46.3	13.174	6	11.3	10.8	5.08	8.25	36.5	BUI	IT-1976-0030	-86.7344	-79.4974	-78.8255
3	20-05-12	2:03:50	44.8955	11.2635	6.1	9.5	16.1	4.34	8.97	83.1	MRN	IT-2012-0008	-257.2346	-258.7973	297.3042
4	29-05-12	7:00:02	44.8417	11.0657	6	8.1	16.8	7.64	13.58	66.8	CRP	IT-2012-0011	117.1082	172.7792	-83.2411
5	29-05-12	7:00:02	44.8417	11.0657	6	8.1	17.5	8.15	9.99	274.4	FIN0	IT-2012-0011	207.7426	-234.2827	189.0658
6	29-05-12	7:00:02	44.8417	11.0657	6	8.1	15.8	3.56	5.13	129.5	MOG0	IT-2012-0011	235.6158	167.0749	124.1752
7	29-05-12	7:00:02	44.8417	11.0657	6	8.1	16.9	7.16	8.06	232.6	SMS0	IT-2012-0011	174.1668	-175.3305	-101.5088
8	29-05-12	7:00:02	44.8417	11.0657	6	8.1	14.4	4.86	6.68	267	T0800	IT-2012-0011	-330.6002	-248.9307	-313.8456
9	29-05-12	7:00:02	44.8417	11.0657	6	8.1	14.3	5.69	11.29	296.9	T0811	IT-2012-0011	-189.3182	-201.9668	124.2583
10	29-05-12	7:00:02	44.8417	11.0657	6	8.1	15.5	8.4	9.18	216	T0812	IT-2012-0011	-138.725	-184.6639	-108.8539
11	29-05-12	7:00:02	44.8417	11.0657	6	8.1	10.7	4.86	6.11	164.9	T0818	IT-2012-0011	238.4351	274.0546	-205.413
12	29-05-12	7:00:02	44.8417	11.0657	6	8.1	14.2	9.4	15.19	0.005	T0824	IT-2012-0011	223.9723	141.7775	92.2776
13	29-05-12	7:00:02	44.8417	11.0657	6	8.1	11.2	5.92	6.98	195.9	MIR03	IT-2012-0011	-204.0962	320.9977	-398.2905
14	29-05-12	7:00:02	44.8417	11.0657	6	8.1	13	5.37	6.52	223.1	MIR04	IT-2012-0011	392.1106	-301.1975	258.2568
15	29-05-12	7:00:02	44.8417	11.0657	6	8.1	15.8	10.62	11.25	192	MIR05	IT-2012-0011	173.8671	269.3132	-148.8766
16	29-05-12	7:00:02	44.8417	11.0657	6	8.1	8.6	3.41	5.03	192.7	MIR08	IT-2012-0011	218.9704	-242.97	-306.6741
17	29-05-12	7:00:02	44.8417	11.0657	6	8.1	9.9	0	3.72	206	T0802	IT-2012-0011	-258.796	290.708	170.588
18	29-05-12	7:00:02	44.8417	11.0657	6	8.1	6.1	0	6.08	136	SAN0	IT-2012-0011	-170.893	-216.652	-306.162
19	22-12-03	11:15:56	35.71	121.1	6.5	4.7	12.7	0	0	0	Cambria	San Simeon	179	0	0

The acceleration response spectra (considering 5% damping ratio) of the individual records selected (grey lines), along with their mean and mean ± one standard deviation (σ) response spectra (solid and dashed red lines respectively) are depicted in Fig. 1 (left). Comparison of the mean and mean ±1σ spectra to the response spectra of the NS and EW components of the recorded motion at DURR station (solid and dashed black lines) indicates a sufficient matching, mainly at the spectral plateau range. The matching is improved when the geometric mean response spectra GMRotI50 (Boore et al. 2006) is considered for the recorded motion, which is independent of the orientation (Fig.1, right).

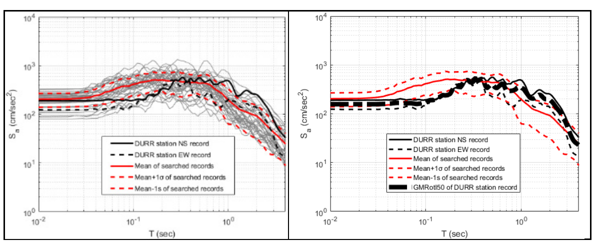

Fig. 1. Elastic response spectra of Durrës (NS and EW) recorded motion, mean spectra ±1σ of the selected records.

3 COMPARISON OF SEISMIC DEMAND AND SEISMIC CODE PRESCRIPTIONS (KTP-N.2-89 & EUROCODE 8)

The elastic response spectra of the recorded motion at DURR station and the mean spectra of selected records should be compared to the relevant elastic spectra of the Albanian seismic code (KTP-N.2-89) and Eurocode (EC8) in order to evaluate the seismic performance of buildings designed according to current code provisions. Site characterization based on EC8 and on Albanian seismic code (KTP-N.2-89) should be accounted for, and the site conditions at Durrës and Thumanë area should be considered.

Since geophysical and geotechnical data are not available, inferred values of V_{s30} based on the geology of Durrës broad area are used. Furthermore, the V_S profile of Durrës accelerometric station (Duni, 2013) could be considered taking into account the fact that the station is installed on soft soil formations that are not necessarily indicative of the soil profile of Durrës area in general.

The V_{s30} values considered are depicted in Fig 2 (left) for the broader region of Durrës, extracted from USGS online application. The V_{s30} values, for the region considered, are inferred from the local geology (Shehu et al. 1983) and slope gradient according to the method recommended by Stewart et al. (2014). For DURR station, the measured V_{s30} value reported in Duni (2013) is about 202 m/s, whereas the inferred value is about 226 m/s. The inferred V_{s30} values reported in Fig.2 (left) suggest that ground types C and D, per EN1998-1, apply on the area of Durrës and ground type C applies on Thumanë (upper pointer on Fig 2 (left).

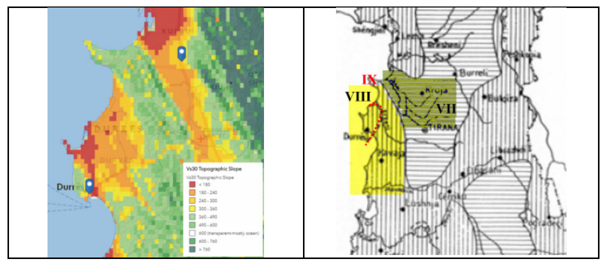

Fig. 2. V_{s30} values at Durrës and Thumanë area (left). Seismic intensity at Durrës and Thumanë area (right)

Since the majority of buildings in Durrës have been constructed after 1990, the prescriptions of KTP-N.2-89 Albanian Seismic Code have been applied. Therefore, the design spectra of KTP-N.2-89 and the relevant of Eurocode 8 are presented and compared herein with a view to highlight the design code requirements and relate them to current code provisions.

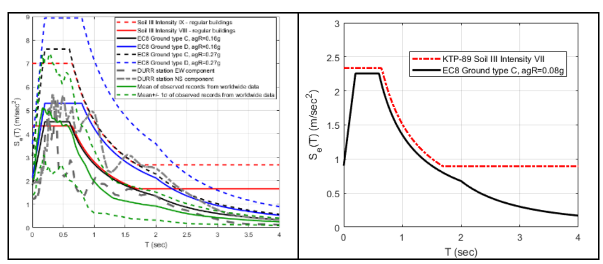

Fig. 3. Comparison of Elastic Spectra (EC8, KTP-N.2-89, DURR, selected motions) at Durrës area (left). Comparison of Elastic Spectra (EC8, KTP-N.2-89) at Thumanë area (right).

Based on the microzonation map (MSK-64), the seismic intensity at Durrës area is VIII and IX, therefore the seismic coefficient is 0,26g and 0,42g for soil type III (a_{gR}=0,16g and 0,27g respectively). At Thumanë area, the seismic intensity is VII and the seismic coefficient is 0.14 for soil type III (a_{gR}=0,08g). Comparison of elastic spectra of KTP89, EC8, components of recorded motion at Durrës station and mean spectra of selected motions (Fig 3-left) highlights that KTP design spectrum (VIII&IX) is in good agreement with the EC8 spectra for soil type C (however not for soil type D) and recorded motion spectra (NS and EW components). For Thumanë, the KTP and EC8 elastic spectra are in good agreement for lower periods (Fig. 3-right)

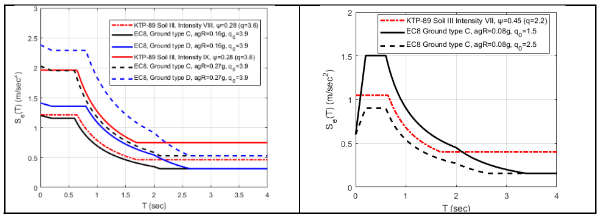

Fig. 4. Comparison of Inelastic Spectra (EC8, KTP-N.2-89) at Durrës area (left). Comparison of Inelastic Spectra (EC8, KTP-N.2-89) at Thumanë area (right).

Inelastic spectra at Durrës (Fig.4-left) and Thumanë (Fig.4-right)area are calculated for the seismic intensities and soil types mentioned above.The q-factor is estimated based on the code (KTP & EC8) provisions, considering structural type and material.

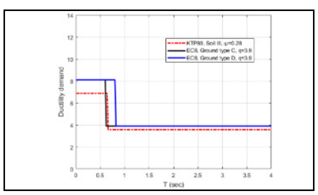

Fig. 5. Ductility μ for Durrës area– Elastic/Inelastic spectral value

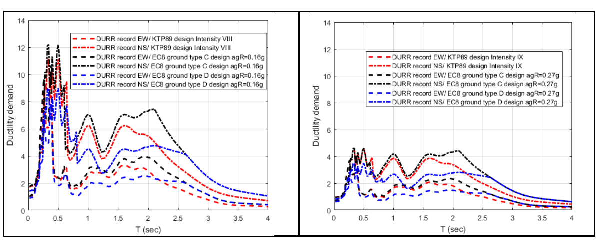

Fig. 6. Ductility demand for Durrës area - Elastic Spectral Values of EW and NS components / Design Spectral values of KTP89 and EC8 for Intensity VIII and a_{gR}=0,16g (left) and for Intensity IX and a_{gR}=0,27g (right)

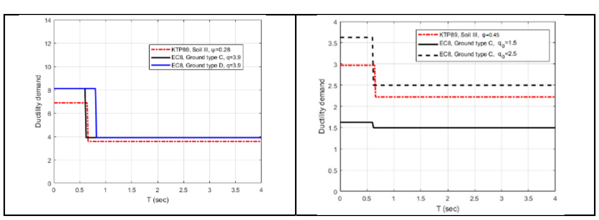

Fig. 7. Ductility μ for Thumanë area – Elastic/Inelastic spectral values

As depicted in Fig. 5 to 7, the ductility demand is higher than the available ductility for a period range T= 0,3-0,7 sec), i.e. for low to medium height buildings.

4 STRUCTURAL DAMAGE

Structural damage observed in Durrës and Thumanë during a recent field mission by the authors, is depicted in Fig. 8 for two typical structural types at Durrës (Fig. 8-left) and Thumanë (Fig.8-right). Slight to moderate damage was observed in Durrës and moderate to major at Thumanë, while the damage level is related to the available ductility for each structural type (Fig. 5 to 7)

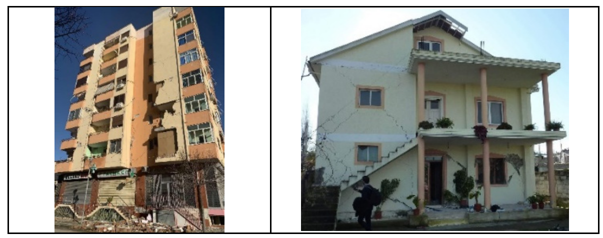

Fig. 8. Typical structures at Durrës and Thumanë area

5 CONCLUSIONS

Based on the above, the main outcome of the comparative assessment of ground motion, design requirements and structural performance is that the design requirements of KTP89 are less strict than EC8 and should be updated, however damage of buildings is mainly due to the fact that code provisions and requirements were not followed and buildings were constructed in phases by the owners, lacking in many cases supervision by civil engineers.

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