EVALUATING THE KAHRAMANMARAS EARTHQUAKE OF FEBRUARY 6 2023 IN TURKEY BASED ON NEW GENERATION ATTENUATION GROUND MOTION (NGA) MODELS

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ABSTRACT

The study briefly describes the February 6, 2023 Kahramanmaras-Turkiye earthquake region's past and current seismotectonic characteristics and use several New Generation Attenuation (NGA) equations to discuss some big ground motion records that occurred on February 6, 2023. Over 500 different worldwide NGA equations in the literature are reviewed. Only seven of them are selected due to the lack of earthquake data obtained from the AFAD (The Disaster and Emergency Management Presidency of Turkey). The available data are epicentral distance, moment magnitude, focal depth and $V_{s,30}$. The results showed that the most of records did not fit the NGAs and interestingly did not decrease as the epicentre increase. Such figure is not expected because the Peak Ground Acceleration (PGA) is expected to drop as the recording station is further from the fault plane. This study aims to discuss some possible reasons of why the records did not fit the NGA equations and briefly discuss the earthquake region.

Keywords: 6 February 2023 Kahramanmaras-Turkiye earthquakes; New Generation Attenuation (NGA) equations; Seismotectonic characteristics of the region

INTRODUCTION

The Mw 7.7 and 7.6 Kahramanmaras Earthquakes struck South-Eastern (SE) Turkiye on 6th February, 2023 and these were larger and more destructive than what had been expected for the tectonic setting on East Anatolian Fault (EAF) zone. These major earthquakes occurred consecutively at local times of 4:17 and 13:14 on the same day, and the epicenters of those were Pazarcik and Elbistan districts of Kahramanmaras province. The first earthquake occurred on a secondary fault, the transfer of stress from which triggered around 300km northeast-southwest rupture of the EAF zone as shown in **Figure 1**. The second major earthquake, approximately nine hours later, occurred on the Sürgü Çardak fault in around 100km northeast of the epicentre

of the first quake. In the region, several significant aftershocks were recorded at many stations operated by AFAD and the sequence of mainshocks and aftershocks are recognized as the Kahramanmaras Earthquake Sequence. These quakes caused major impacts on superstructures and infrastructure throughout SE Turkiye and North-Western (NW) Syria. **Table 1** shows the five largest magnitudes and the local coordinates of the epicenter of these main earthquakes.

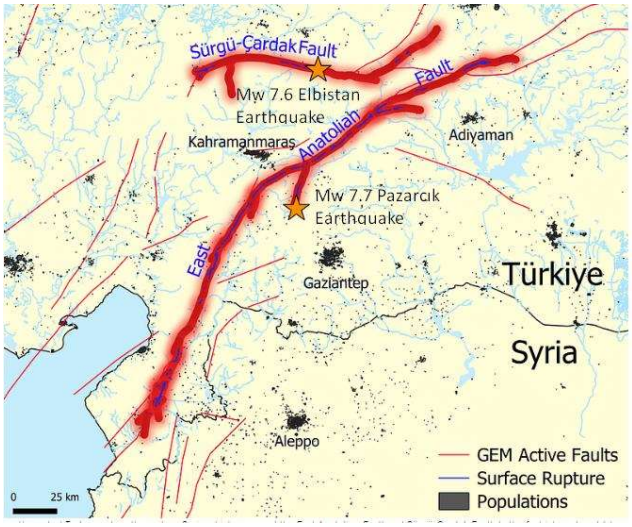


Figure 1. The location of the epicenters of the February 6 earthquakes in Turkey on the EAF zone

Table 1. Important data for the largest magnitude of Kahramanmaras Earthquake [1].

Earthquake ID	*Date (m/d/y hour)*	*City*	*District*	*Lat. [º]*	*Long. [º]*	*Mw*	*Depth [km]*	*Mechanism*
543428	02/06/2023 04:17	Kahramanmaras	Pazarcik	37.288	37.043	7.7	8.60	Strike-slip
543431	02/06/2023 04:28	Gaziantep	Nurdagi	37.304	36.920	6.6	6.20	Strike-slip
543430	02/06/2023 04:36	Gaziantep	Islahiye	37.128	36.639	5.7	11.19	Strike-slip
543593	02/06/2023 13:24	Kahramanmaras	Elbistan	38.089	37.239	7.6	7.00	Strike-slip
551067	02/20/2023 20:04	Hatay	Yayladagi	36.037	36.021	6.4	21.73	Strike-slip

According to AFAD [2], total loss of life is over 50000. This event is regarded as one of the worst catastrophes known to modern Turkish history, exceeding the devastation of the Mw7.8 Erzincan earthquake in 1939. As a result of the damage assessment studies carried out in 11 provinces of Turkiye affected, 1895348 buildings were identified, of which 303455 were to be destroyed, heavily damaged or moderately damaged [3].

This study reviews over 500 different NGA equations employed for around the world in the literature. Due to limited number of earthquake data (which is epicentral distance, moment magnitude M_W, focal depth and $V_{s,30}$) obtained from the AFAD (Disaster and Emergency Management Presidency of Turkey), only seven of NGAs shown in **Table 2** (Yu and Wang [4]; Herak, Markušić [5]; Güllü, Ansal [6]; Ulusay, Tuncay [7]; Segou and Voulgaris [8]; Bindi, Luzi [9]; Akkar, Sandıkkaya [10]) were selected. The ground motion data, which ranges

between 300m/s<$V_{s,30}$<500 m/s and 500m/s<$V_{s,30}$<700m/s, was taken into consideration for reasonable comparisons between the NGAs. All of the chosen NGAs are for faults with strike-slip, which account for most earthquakes in Turkey [3]. Additionally, two studies that do not take into account soil locations are also plotted separately for records (Yu and Wang [4] and Herak, Markušić [5]).

Table 2. Showing horizontal New Generation Attenuation (NGA) equations of seven studies adopted in this study.

Author	Region	Ground-motion models (PGA: maximum of two components)
Yu and Wang [4]	Western North USA	No $V_{s,30}$ limit (or no soil site classes in model) $\log PGA = 0.617 + 1.163M_S - 0.046M_S^2 - 2.207\log [R_{epi} + 1.694exp(0.446M_S)]$
Herak, Markušić [5]	Southern Europe	No $V_{s,30}$ limit (or no soil site classes in model) $\log PGA = -1.300 + 0.331M_L - 1.152log\sqrt{R_{epi}^2 + 11.8^2} + 0.311$
Güllü, Ansal [6]	Turkiye	for $V_{s,30} < 500m/s$ (S=1) and $V_{s,30} > 500m/s$ (S=0) $\ln PGA = 0.192 + 0.867M_w - 0.294\ln R_{epi} - 0.008R_{epi} + 0.113S$
Ulusay, Tuncay [7]	Turkiye	for $300m/s < V_{s,30} < 700m/s$ $PGA = 2.18e^{0.0218(33.3M_W - R_{epi} + 7.8427)}$
Segou and Voulgaris [8]	Europe and Middle East	for $360m/s < V_{s,30} < 760m/s$ and strike-slip fault $\log PGA = 1.92909 + 0.21829M_W + 0.00328M_W^2 + (-1.0675 + 0.01016M_W)\log\sqrt{R_{epi}^2 + (H - 0.01005)^2} + 0.08438 + 0.12297$ H=focal depth
Bindi, Luzi [9]	Italy	for $400m/s < V_{s,30} < 800m/s$ $\log_{10} PGA = 1.344 + 0.328M_W - 1.09\log_{10}\sqrt{R_{epi}^2 + 5^2} + 0.262$
Akkar, Sandıkkaya [10]	Europe and Middle East	for $180m/s < V_{s,30} \le 800m/s$ and strike-slip fault. Fixed to $V_{s,30} = 400m/s$ and $V_{s,30} = 600m/s$ for only comparison with others $\ln Y = \ln Y_{REF} + \ln S$ $\ln Y_{REF} = 2.52977 + 0.0029(M_W - 6.75) - 0.05496(8.5 - M_W)^2 + [-1.31001 + 0.2529(M_W - 6.75)]\ln\sqrt{R_{epi}^2 + 7.5^2}$ for $M_W \le 6.75$

		$\ln Y_{REF} = 2.52977 - 0.5096(M_W - 6.75) - 0.05496(8.5 - M_W)^2 + \left[-1.31001 + 0.2529(M_W - 6.75)\right] \ln\sqrt{R_{epi}^{\ 2} + 7.5^2}$ for $M_W > 6.75$ $PGA_{REF} = \exp(\ln Y_{REF})$ $\ln S = -0.41997 \ln(V_{s,30}/750) - 0.288461 \ln\left[\frac{PGA_{REF} + 2.5(V_{s,30}/750)^{3.2}}{(PGA_{REF} + 2.5)(V_{s,30}/750)^{3.2}}\right]$ for $V_{s,30} \le 750$ $\ln S = -0.41997 \ln\left(\frac{\min(V_{s,30}, 1000)}{750}\right)$ for $V_{s,30} > 750$

DISCUSSION FOR RECORDED EARTHQUAKES

In **Figure 2**, the biggest horizontal earthquake records are plotted with the NGAs after the classifications. A few records shown in **Figure 2** align between 10 and 35 km, but most of the data does not match the curve beyond the epicentral (R_{epi}) distance of 35 km. As the recording station gets farther from the fault plane (as R_{epi} > 35km for this investigation), the PGA is generally expected to decline. The nature of the earthquakes or the presence of several fault breaks may be to blame for such unusual records. As shown from **Figure 2a** and **Figure 2b**, the earthquake with magnitude of Mw7.7 had a maximum horizontal acceleration of approximately 2.2g and the vertical acceleration close to 2g. When compared to previous earthquakes in the area, such massive accelerations are never seen before.

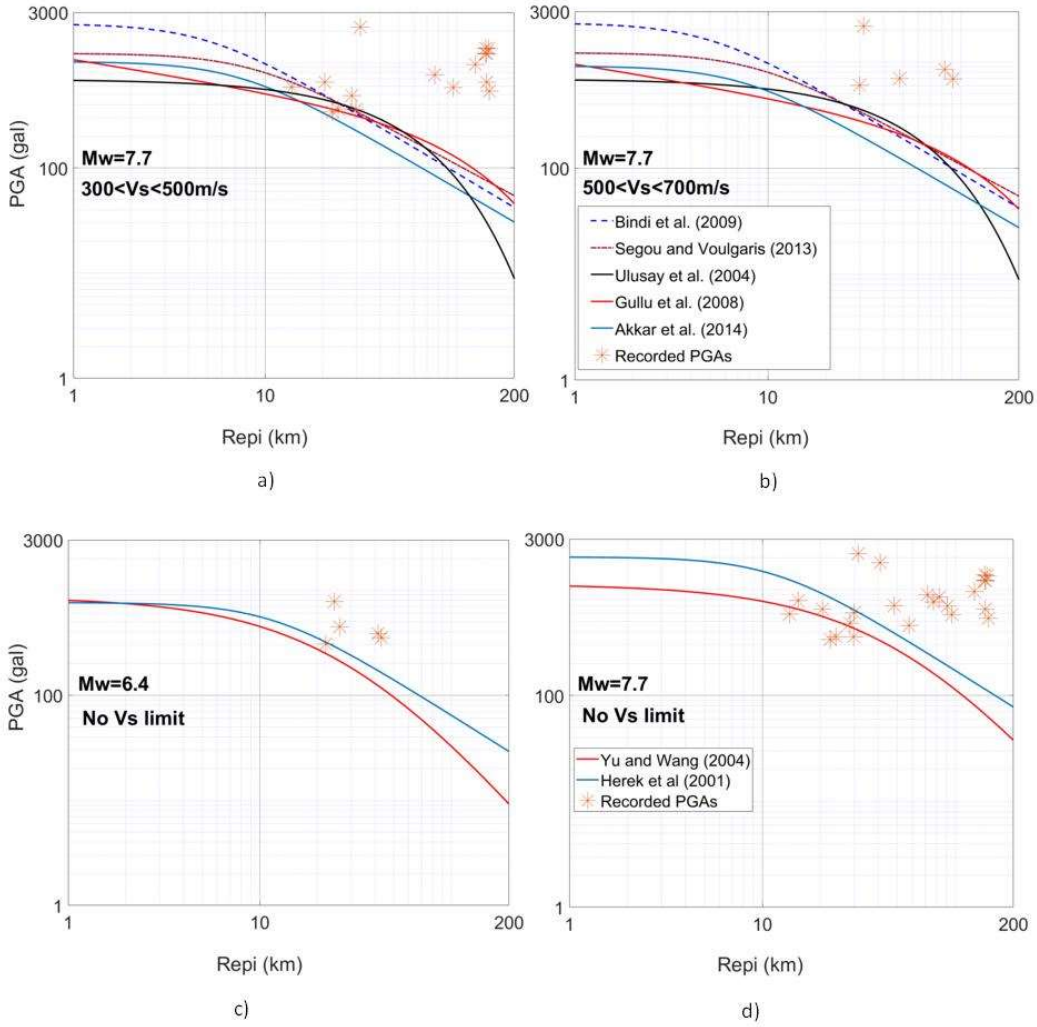


Figure 2. Comparison of the New Generation Attenuation (NGA) equations for **a)** Mw=7.7 and 300<Vs<500m/s, **b)** Mw=7.7 and 500<Vs<700m/s, **c)** Mw=6.4 and no Vs limit and **d)** Mw=7.7 and no Vs limit

CONCLUSION

In this study, seven New Generation Attenuation (NGA) equations based on a worldwide database were used for the February 6, 2023, Kahramanmaras earthquakes in Turkiye. An attempt was made to use these NGAs to evaluate the records of the earthquake. It showed that the earthquake records did not match the equations as expected. Therefore, there is a need to investigate why Peak Ground Acceleration (PGA) did not decrease as epicentre distance increased. In the authors' opinion, this may be due to more than one fault break in EAF zone or the nature of the earthquake.

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