Analyzing the Seismic Activity in Dodoma City and Insights on Possible Hazard Mitigation Strategies and Technologies for the City

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Abstract— *Dodoma, the capital city of Tanzania, lies within the East African Rift System (EARS) prone to earthquake of moderate to strong ground shaking. In the recent years, Dodoma area has been hit by earthquakes with considerable damages to build environments as the case for the magnitude 5.5 earthquakes of November 2002 that induced several cracks to National Parliament building and brought several panics to Tanzanian Members of Parliament who was in the session. By revisiting the geologic setting of Dodoma, earthquake activities and the current technologies for earthquake monitoring in the urban areas, the study proposes the community earthquake monitoring network for Dodoma City and the nearby populations that are currently dwelling in background with possibility for earthquake of magnitude larger than 5. The proposed network of seismic sensors can help in providing 10 seconds of warning times to Dodoma city dwellers.*

Keywords— ***Earthquake, MEMS Seismic sensors, Seismic sensor networks, seismic hazard, seismic alerts.***

I. INTRODUCTION

The Dodoma city lies in a region where the eastern branch of the East African Rift System dies out into the craton. The area is characterized by low- to moderate-magnitude seismic activity, with few large earthquakes of up to magnitude 6.2, capable of inducing small to medium damages to build infrastructures.

On November 4, 2002, Dodoma, the capital city of Tanzania was hit by an earthquake of magnitude 5.5 during the parliament session, causing panics to Member of Parliament and inducing several cracks to the parliament building [6]). Surface dislocations in the form of fractures were also reported by local villagers in their fields, in the Chenene Mountains close to the Great North Road and near Chenene village (Macheyeki et al., 2008).The epicenter for the event was within the Chenene Mountains that lies within an area between the Bubu fault and Hombolo fault. Also, the magnitude 6.1 earthquake of 7 May 1964, which occurred along the southern border of the Eyasi basin, was strongly felt in the region. Most recently, on 13 July 2016 an earthquake of magnitude 5.1 according to NEIC occurred about 62 km from Msanga and about 79.3 km from Dodoma, the Capital city of Tanzania [12]. The intensity of the event in Dodoma city as reported by USGS system was about 4 Modified Mercalli Intensity (MMI) scale, which is high enough to be felt by people dwelling in Dodoma city as well as neighbouring towns and villages. This event was felt up to a distance of about 500 km away, and as far as Nairobi, Kenya. Although Tanzania operates the National broadband seismic stations closer to the event epicenter, until the writing of this document, no processed data for the event from the Tanzanian seismic station were available on the international seismic bulletins for the event [13].

The tectonic study, active faults identification and the seismic sources characterization with respect to the locations of urban areas in the region by Daudi [2] and Msabi [3], have also indicated that most of the seismic generated frequencies from the EARS sources may reach the Dodoma urban sites with significant amount of energy. Further study undertake by Lupogo et al [4] on seismic site effects of the Dodoma area based on qualitative characterization of the local soil conditions and the expected influence in amplification during the earthquake, provides characterization of seismic generated ground shaking amplification effects for the urban area of Dodoma shown in Figure 1.

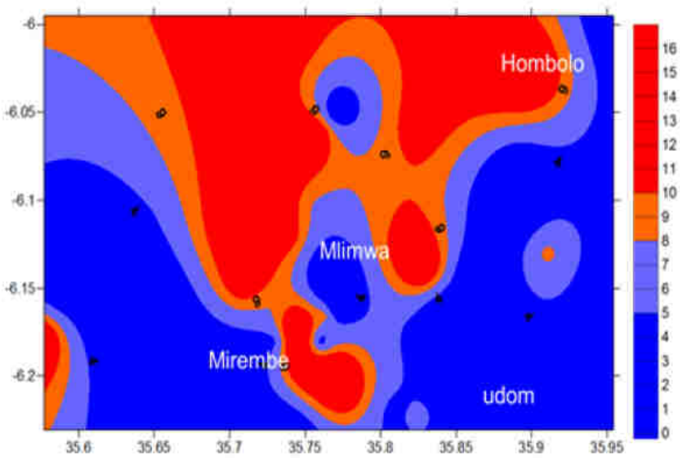

Fig.1: Earthquake amplification map for urban area of Dodoma,[4]

From Figure 1, seismic ground vibration of up to 16 times is expected in areas like Hombolo and some parts of Mirembe, while Udom falls in area with ground vibration amplification of up to 5 times than the original vibrations at the source. That is, even for small ground vibrations induced by the earthquakes that reach Dodoma area, built infrastructures in Hombolo area are at more risk of collapsing than that in Udom area.

Earthquakes hold the potential to deliver devastating blows to urban areas with projected losses of up to a quarter-trillion dollars from a single event [12]. As the population increases in Dodoma city, expanding urban development are likely to encroach upon even the areas susceptible to more amplifications to earthquakes ground motions, increasing the risk to life and property damages. As a rule of game, when you are in an area where earthquakes risks is high, it is recommended to consider the inclusion of earthquakes overall emergency response strategies and technologies into the development plans. The buildings must be built to a higher standard of construction with strict earthquake based building codes. For the safety of economic investment and development that are currently being undertaken in Dodoma, the capital city of Tanzania, the geological history of the Dodoma region must be considered in all engineering projects such as road construction industry, mining and urban development, as well as all technological communication infrastructure building projects.

II. METHODOLOGY

Methodology adopted in this study, starts with the evaluation of seismic velocities in the region using ISC phase arrival time of P and S-waves at the global seismic station located within the region. From the current seismic sensor technologies adopted around the world, and from the sensor types available in communication devices used by people dwelling in Dodoma, feasible sensors technologies for monitoring earthquakes near Dodoma city is selected. Then, using the epicenter positions of historical earthquakes, the positions for the community sensor stations is proposed via simulation of warning times with respect to selected target sites in Dodoma city.

III. SEISMIC ACTIVITY OF DODOMA CITY AND SURROUNDING AREAS

From the ISC catalogue, events recorded in the region with epicentral distance to be of danger to the Dodoma city between 2002 and July 2016, are shown in Figure 2.

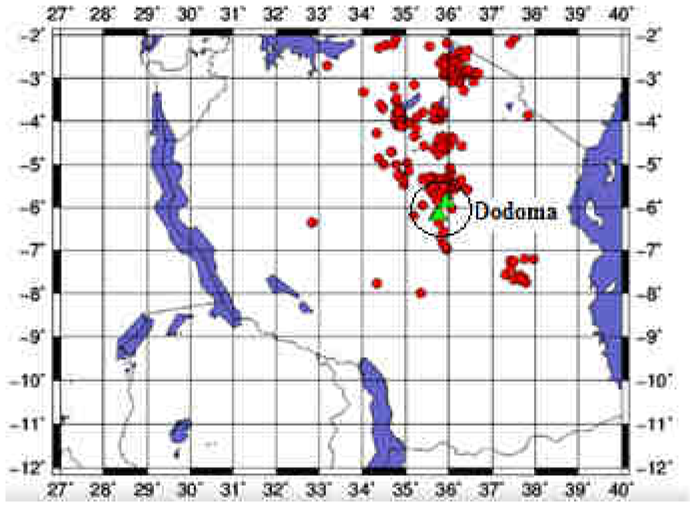

Fig.2: Seismicity closer to Dodoma between 2002 and July 2016

From Figure 2, the seismic activity closer to Dodoma shows that the area is indeed seismically active and prone to large.

Earthquakes with magnitudes ranging from magnitude 3.7 to 5.5 are common to have hit the northern part of Dodoma for many years [7] – [8]. The earthquakes in Dodoma area tend to occur in swarms and the last strong event culminated by the November 4, 2002, magnitude 5.5 earthquakes that struck the Chenene Mountains, 80 km north of Dodoma. Few people were reported dead, a school and a dispensary destroyed, and the old Tanzania parliamentary building located in Dodoma, cracked.

IV. POSSIBLE SENSOR TECHNOLOGIES FOR SEISMIC MONITORING IN DODOMA

Many personal communication devices that community dwellers are using to connect to internet are either built-in with MEMS accelerometer or can be connected via USB to MEMS accelerometer sensors. The MEMS accelerometers are the state of art low cost seismic sensor technologies being utilized for monitoring earthquakes in urban area for early warnings to reduce seismic related losses [10]. Most modern laptops or mobile phones are built with MEMS accelerometers and by networking the devices, a low-cost seismic network for collecting earthquake generated seismic waves can be formed [11].

Community earthquake Early Warning Systems (CEEWS) based on MEMS accelerometers are operational in several regions around the world [1]. The CEEWS captures the earthquake propagating waves and send the data to the central server where installed algorithms processes the data to infer danger zones and send early warning alerts. The warning times in current CEEWS varies according to the distances between seismic source, seismic sensor detecting the event and user sites location with respect to event. The warning time of up to 70 seconds has been realized in some CEEWS , but for personal protection, even few tens of seconds of warning time has been proven to be enough for people to quickly move to safe-zones such as under sturdy table, or move away from hazards including falling book shelves and windows [5]. Because wireless communications, the major requirement for sensor operation, is widely available in Dodoma city, MEMS accelerometer seismic sensors has been proposed as feasible technology for monitoring earthquakes in Dodoma.

V. EVALUATION OF SEISMIC VELOCITIES AND PROPOSED SENSOR NETWORK AROUND DODOMA

Using the ISC seismic phase arrival times reported by seismic stations in the region for earthquakes with source near Dodoma, P-wave velocity has been analyzed to be between 5.9 km/s and 8 km/s while the velocity for S-wave ranges between 3.5 km/s and 4.8 km/s [1]. Using the magnitude 5.3 earthquake of November 4, 2002 as the case study, the P-wave and S-wave velocities for the region has been simulated in this work to be 7.5 and 3.5 .for P-wave and S-wave respectively. The same range of seismic wave (P and S-wave) velocities across the region has been also evaluated by analyzing the ISC station phase arrival data for earthquakes originating closer to Dodoma as recorded by seismic stations along EARS.

According to the seismic activity and tectonic setting around Dodoma, epicentral distances for the earthquake that poses danger to Dodoma city (Figure 3) can be as low as 70 km away. Simulating the repeats of magnitude 5.3 earthquake of 2002 in Dodoma, for warning time of 10 seconds to allow people in the city to take cover in safe places to minimize losses, the proposed network of seismic sensors relative to the earthquake ground shaking is shown in Figure 3.

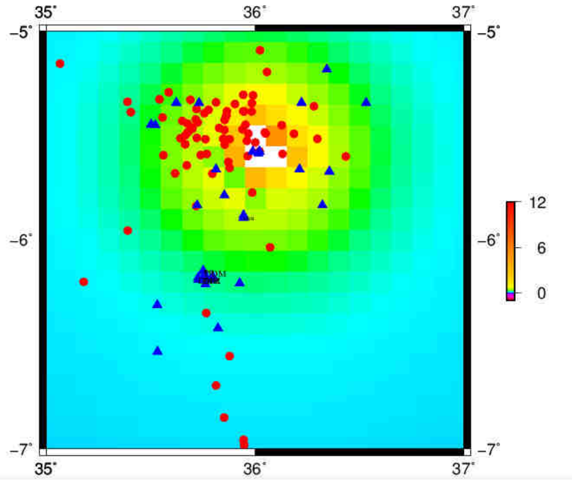

Fig.3: Ground shaking from magnitude 5.3 earthquake and proposed positions for seismic sensors. Blue triangles are seismic station and red circles are other earthquake.

The shaking in red to blue is the shaking of the case study earthquake.

The warning times calculation utilizes the time for the earthquake waves to travel from the source to recording stations, the time for communication of data to processing center and the time for the seismic waves to start shaking the protected site. The seismic station were assumed to be the low cost MEMS accelerometers in smart phones, the MEMS accelerometers that are connected via USB to computers, as well as the MEMS accelerometers built into laptops. The protected sites were the selected sites in Dodoma city, which included the parliament building, University of Dodoma, Hombolo, and Mirembe. The time for arrivals of P-waves and S-waves propagating from the earthquake source to the first five stations were used in the calculation of warning times, as detailed in another paper (Manyele, 2016).

From the earthquake ground shaking in Figure 3, red-orange colour implies severe and hazardous ground shaking accompanied by possible damages to build environment, green colour implies strong shaking with minor damages, and blue colours implies low shaking without damages. That is, Dodoma city is simulated with strong ground shaking as was the case for the earthquake felt reports.

VI. CONCLUSION

Indeed the seismic activity around Dodoma city poses some challenges for city dwellers. The fast speed of building the infrastructure for this capital city of Tanzania should go in hand with utilization of seismological knowledge in order to build structures that can cope with the expected level of earthquake ground shaking. Also, because cheaper technologies of MEMS based accelerometers are available in most communication devices, city dwellers should be educated to participate in building denser community based seismic networks. Community based seismic networks will provide alerts for city dwellers to avoid dangers.

REFERENCES

[1] Manyele A, and Mwambela A." Event Detection Time Delays from Community Earthquake Early Warning System Experimental Seismic Stations implemented in South Western Tanzania Between August 2012 and December 2013" International Journal Of Advancement In Engineering Technology, Management and Applied Science (IJAETMAS) ISSN: 2349-3224, www.ijaetmas.com,Volume 03 - Issue 08 , August – 2016, | PP. 144-149

[2] Daudi, G. "Investigation of the seismo-tectonic structure of the eastern branch of the East African Rift System in Tanzania", Master thesis. University of Dar es Salaam: Dar es Salaam, 2007.

[3] Msabi, M. "Seismic Source characterization for NTD", MSc thesis. University of Dar es Salaam: Dar es Salaam, 2009.

[4] Lupogo, K. Qualitative Microzonation of Earthquake Susceptibility - A case study for Dodoma Urban Area, Central Tanzania. Tanzania Journal of Earth Science, 2013.

[5] M. Kohler, D., T. H. Heaton, M. H. Cheng, "The Community Seismic Network and Quake-Catcher Network: enabling structural health monitoring through instrumentation by community participants", Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems 2013, edited by J. P. Lynch, C-B. Yun, KW. Wang, Proc. of SPIE Vol. 8692, 86923X, 2013.

[6] Keneth Lupogo (2013). A Review of Engineering Geology in Tanzania. International Journal of Research in Engineering and Science (IJRES) ISSN (Online): 2320-9364, ISSN (Print): 2320-9356 www.ijres.org Volume 1 Issue 8 ǁ Dec 2013 ǁ PP.48-55

[7] Macheyeki AS, Delvaux D, De Batist M,Mruma A 2008 Fault kinematics and tectonic stress in the seismically active Manyara-Dodoma rift branch in Central Tanzania - Implications for the East African Rift .J. Afr. Earth Sci. 51(4):163-188.

[8] Macheyeki AS, Delvaux D, De Batist M,Mruma M 2009 Active faults and fault segmentation in the Dodoma area, Tanzania: A first assessment of the seismic hazard in the area. Tanz. J. Earth Sci. 1: 38-57.

[9] Lawrence J.F., Cochran E.S., Chung A., Kaiser A., Christensen C.M., Allen, R. et al. MEMS: Accelerometers and Distributed Sensing for Rapid Earthquake Characterization. Bulletin of the Seismological Society of America (BSSA), 2014.

[10] E. Cochran, J. Lawrence, C. Christensen, and A. Chung. A Novel Strong-motion Seismic Network for Community Participation in Earthquake Monitoring. IEEE Instrumentation and Measurement Magazine, 2009.

[11] USGS, 2016". http://earthquaketrack.com/quakes/2016-07-13-03-01-15-utc-5-1-10. Last visited Dec 20, 2016.

[12] International Seismological Centre. http://www.isc.ac.uk/ehbbulletin/search/arrivals/ Last accessed 27 June 2016