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REAL-TIME STRONG MOTION NETWORK WITH STRUCTURAL HEALTH MONITORING FUNCTION IN ULAANBAATAR, MONGOLIA

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Abstract

The real-time strong motion network is under construction covering different soil conditions in metropolitan area Ulaanbaatar city, Mongolia. The network has already started to operate with its first 7 sites and planned to be completed with at least more of 16 sites. Additionally, at present 2 buildings are equipped with strong motion instruments dedicated to the on-line structural health monitoring. Both efforts, to construct strong motion network for metropolitan area and to build structural health monitoring system are pioneer in Mongolia. In fact, the Mongolia known as seismic prone country as number of great earthquakes were occurred in the 20th century. The most four major continental earthquakes of magnitude 8 and above (Tsesterleg-1905 Mw=7.9, Bolnay-1905 Mw=8.3, Fu Yun-1931 Mw 8.0 and Gobi-Altay-1957 Mw=8.1) strike Mongolia and formed 180 to 400 km long spectacular ruptures on earth surface. Today, some recent weak motion seismic network observation raises strong concerns on seismic activity around Ulaanbaatar. Newly built strong motion network provides real-time ground motion data from micro tremor to strong motion. Effective use of accurate strong motion data is crucially important to scientific and engineering use for Mongolia. In the meantime, it enables ability to generate information to public such as shake map. Initiative of development of the structural health monitoring study for structural response assessment and real time detection of structural damage in Mongolia, as well as its integration of strong motion network is one of the meaningful task within the project. Based on reliable operation of the strong motion network and SHM systems, earthquake disaster mitigation applications in taking account of the regional distinctive earthquake environment will hopefully be developed.

Keywords: Strong motion, structural health monitoring.

1. Introduction

The "Mongolian University of Science and Technology" (MUST) launches a project in collaboration with "International Research Institute of Disaster Science" (IRIDeS), Tohoku University, Japan for construction of Strong Motion Network (SMN) with Structural Health Monitoring (SHM) function in Ulaanbaatar, capital city of Mongolia. The aim of the project is to construct permanent earthquake ground motion monitoring platform, in fact to build strong motion network that capable of measuring strong shaking associated with damaging earthquakes in the vicinity of Ulaanbaatar. As network data essentially be used for earthquake engineering purposes, structural health monitoring systems are also integrated into the platform. Thus our permanent earthquake ground motion platform intended to enable us possibility to get into field of leading interdisciplinary earthquake engineering research and applications. An alternative outcome of having such system is not only enhancement on higher education and research as tackling the lack of knowledge in field of earthquake engineering of the country but also its social benefit will be noticeable. Current strong motion network realized by collaboration of MUST and IRIDeS consists of 7 strong motion sites and 2 buildings with SHM, and will be extended by fund of "Mongolia-Japan Higher Engineering Education Development" (M-JEED) project. So strong motion network shall be completed by additional 16 sites under the Joint Research Project (J22D16) of M-JEED. Total of 23 strong motion sites will be operational in near future.

2. The seismicity of Mongolia and Ulaanbaatar

The Mongolia known as seismic prone country as great earthquakes were occurred in the 20th century. The most four major continental earthquakes of magnitude 8 and above (Tsesterleg-1905 Mw=7.9, Bolnay-1905 Mw=8.3, Fu Yun-1931 Mw 8.0 and Gobi-Altay-1957 Mw=8.1) strike Mongolia and formed 180 to 400 km long spectacular ruptures on earth surface. Not only these 4 catastrophic earthquake zones but also large numbers of active faults that are capable to produce devastating earthquakes (Mw 6.5+) and it makes the prospect of strong events very concerning.

Recent observations raise strong concerns on seismic activity around Ulaanbaatar. The number of potential and still pourly known fault structures in the region beneath a Hustai, Emeelt, Gunj, Sharkhai, Avdar and Mungunmorit active fault areas which are located about 10 to 100 km from Ulaanbaatar have been discovered. These findings dramatically altered our view on the relative seismic quiescence about Ulaanbaatar (see **Fig.1**).

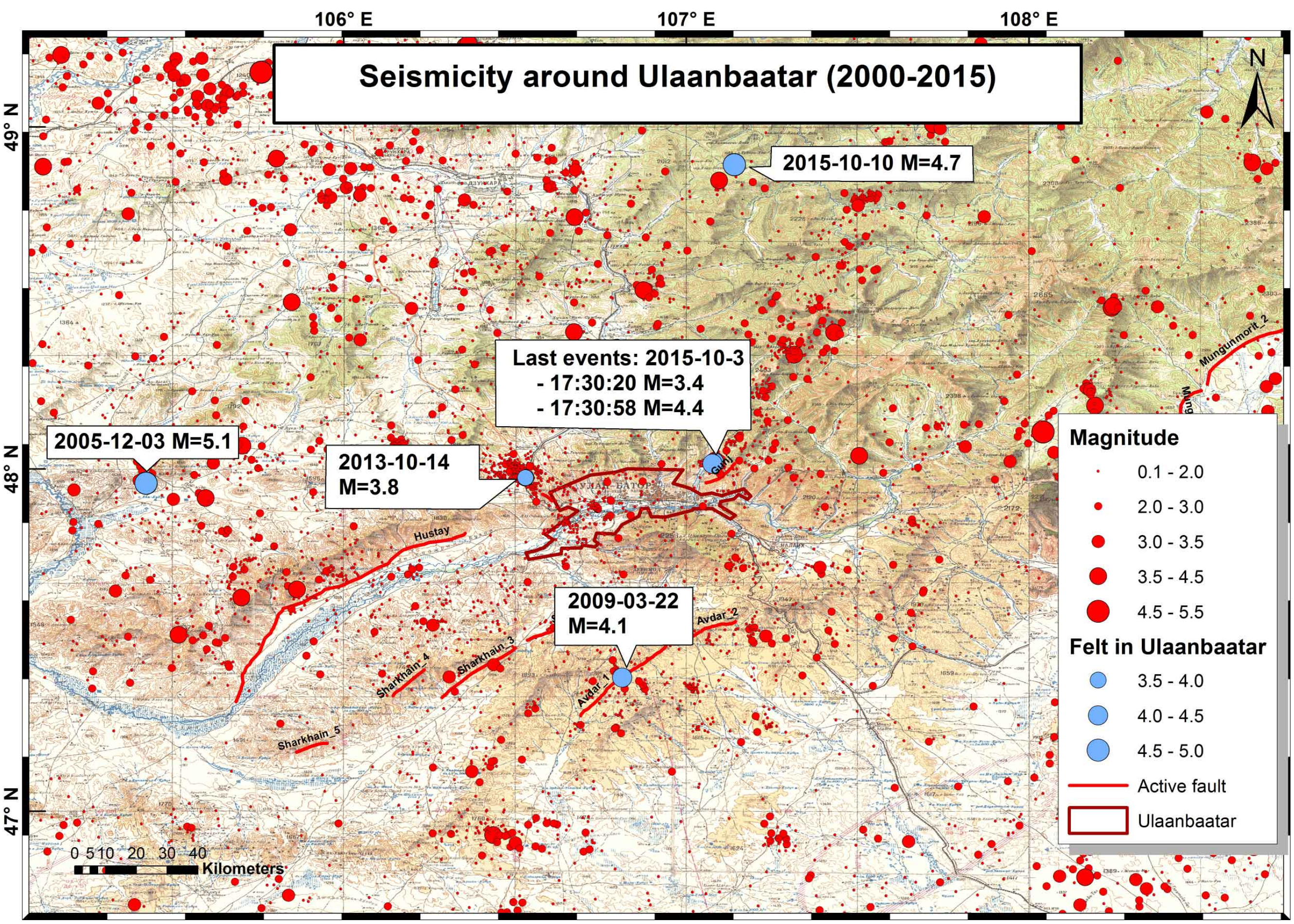

Fig.1 Seismicity map of Ulaanbaatar region for recent 15 years (2000-2015). Blue circles indicate felt earthquakes by Ulaanbaatar citizens. (Source IAG)

The high seismic activity of Ulaanbaatar area starts from middle of 2005 and still continues up to today. Even in the recent years number of events occurred that felt by Ulaanbaatar citizens. The Japan International Cooperation Agency (JICA) project titled "The Project for Strengthening the Capacity of Seismic Disaster Risk Management in Ulaanbaatar City" [5] calculated some earthquake scenarios. According to their result M=7 event able to occurs at Hustai fault, in this case intensity in Ulaanbaatar will be 300cm/sec2 – 400cм/sec2 or VIII – IX in MSK scale depending on engineering geological conditions. This intensity can cause severe damage to the city which is home to one and a half million people.

3. Strong Motion Network and SHM systems in Ulaanbaatar

The strong motion network comprising 23 stations planned to cover Ulaanbaatar city basin, currently 7 strong motion stations have been installed and operational. The map (see **Fig.2**) shows location of strong motion stations installed in Ulaanbaatar. There are 2 types of sensors installed. 3 with Episensor ES-T, Kinemetrics and others with MicroSMA, DAQ Systems. Acquisition systems are uniform, all equipped with NetDAS Seismic/Earthquake Recorder. Data center has been built at MUST, all stations send their data in real-time over the internet. The ground floor of government owned buildings were selected as strong motion sites in considering geological conditions under the site. 2 among 7 currently installed sites serve for both of strong motion network and SHM systems. Sensors at basement floors of instrumented buildings under structural health monitoring planned to be used as strong motion sites.

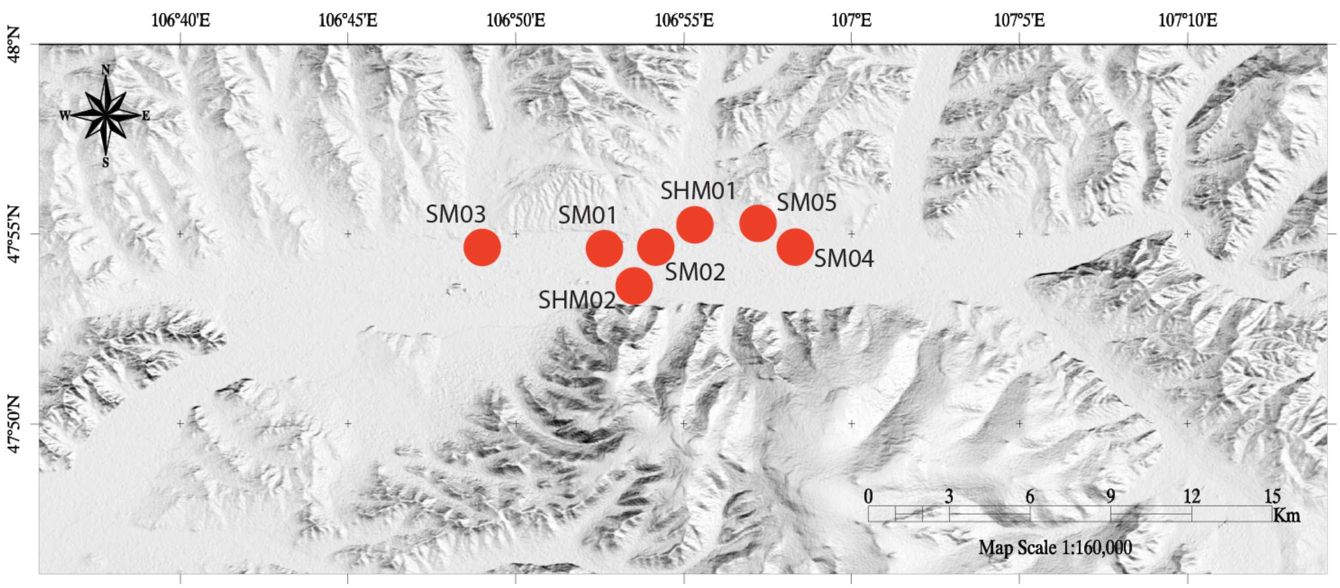

Fig.2 Strong motion station map. Location of strong motion stations (solid red circles), SM stands for strong motion and SHM stands for structural health monitoring sites. Here are 2 stations, SHM01 and SHM02 have to be used for both of strong motion and structural health monitoring purposes.

In the following images (see **Fig.3**) show 2 buildings under structural health monitoring. Both are municipale administration offices.

Fig.3 Buildings under structural health monitoring and relative position of the sensors. (a) SHM01 installed in 15 story building "Khangarid"; and (b) SHM02 installed in 9 story building "Khan-Uul".

Accelerometers located in these buildings are configured to capture any vibration signature of the building/structure from microtremor level to strong motion level. Aim of this installation is to detect any sudden shifts of structural characteristics and also observe how the structure gradually degrades over time. The buildings selected as one of the most common types of structures of the city.

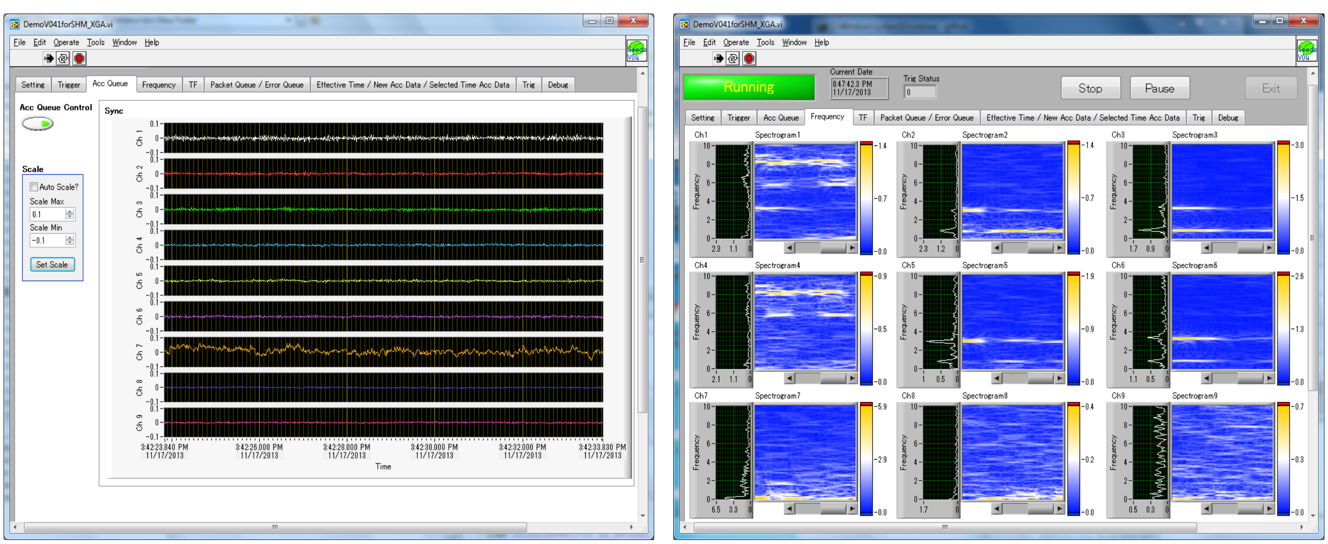

Fig.4 Screenshots of the SHM system. Real time data flow and fast Fourier transform result

4. Preliminary data analysis

Since the installation of the system the number of local earthquakes occurred around Ulaanbaatar city. An earthquake occurred on 10th October 2015 with magnitude M4.7, epicentral distance about 100 km to the north of the capital city (refer **Fig.1**). The acceleration records on the both buildings of city offices were shown in **Fig.5**.

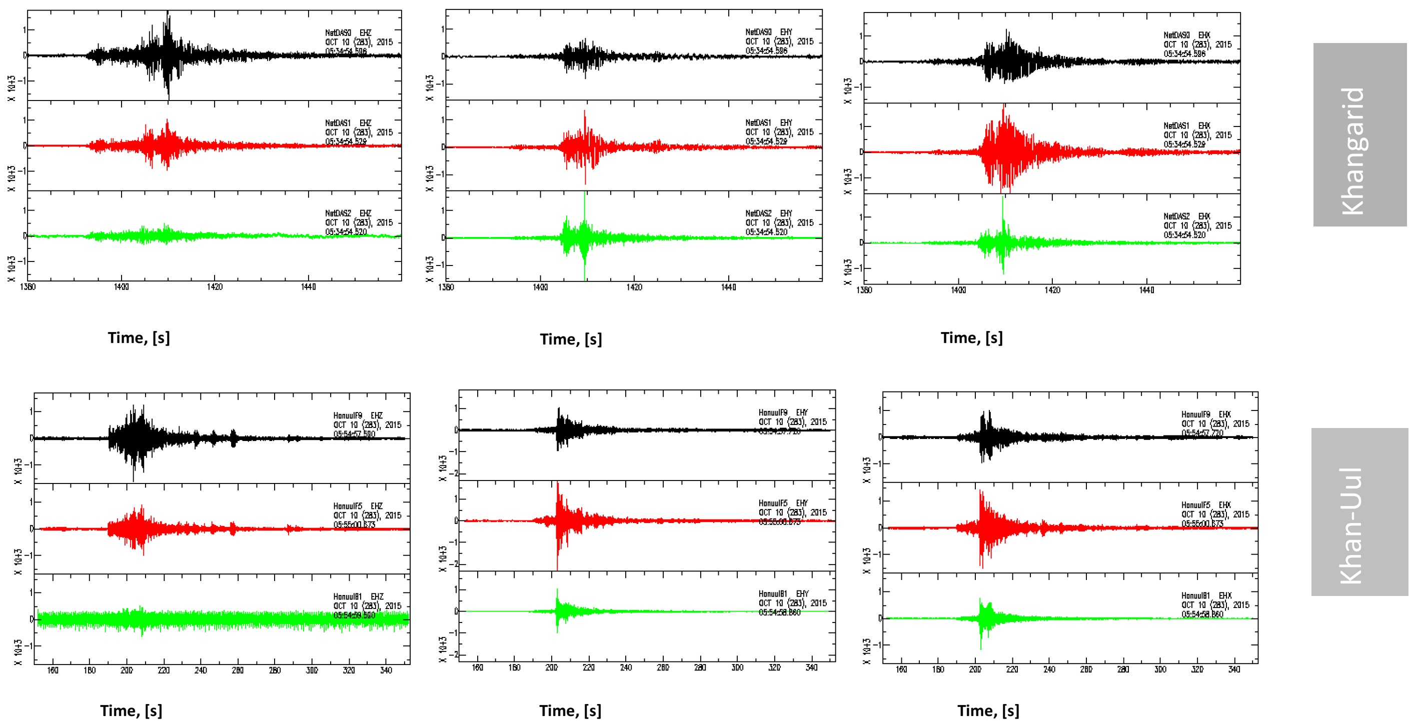

Fig.5 Acceleration records in the buildings of Khangarid and Khan-uul. Sensors are locating in the following floors with corresponding legends. (a). Khangarid building: 15th floor - NetDAS0, 8th floor - NetDAS1, Basement floor - NetDAS2; and (b) Khan-uul building: 9th floor - HanuulF9, 5th floor - HanuulF5, Basement floor - HanuulB1.

The current implementation state is the permanent earthquake ground motion monitoring platform has partly constructed, basic data analysis is started on using collected data archive. **Fig.6** shows the preliminary data analysis of time-frequency on the two horizontal directions of each sensors located at 15th floor, 8th floor, basement floor respectively of the building “Khangarid”. **Fig.7** shoes the velocity response spectra with 5 % damping at the respective floors on the two horizontal directions. **Fig.8** shows the spectral mode information based on microtremor measurement at the top-floor of 15th and at the med-floor of 8th, respectively. The building “Khangarid” is 15 story RC structure which has 1st natural frequency of 0.9Hz in EHX component and 0.8 Hz in EHY component based on the top floor (15th floor); the 2nd mode of the structure is 3.3Hz in EHX component and 3.1Hz in EHY component based on the mid-floor (8th floor) measurement records, respectively.

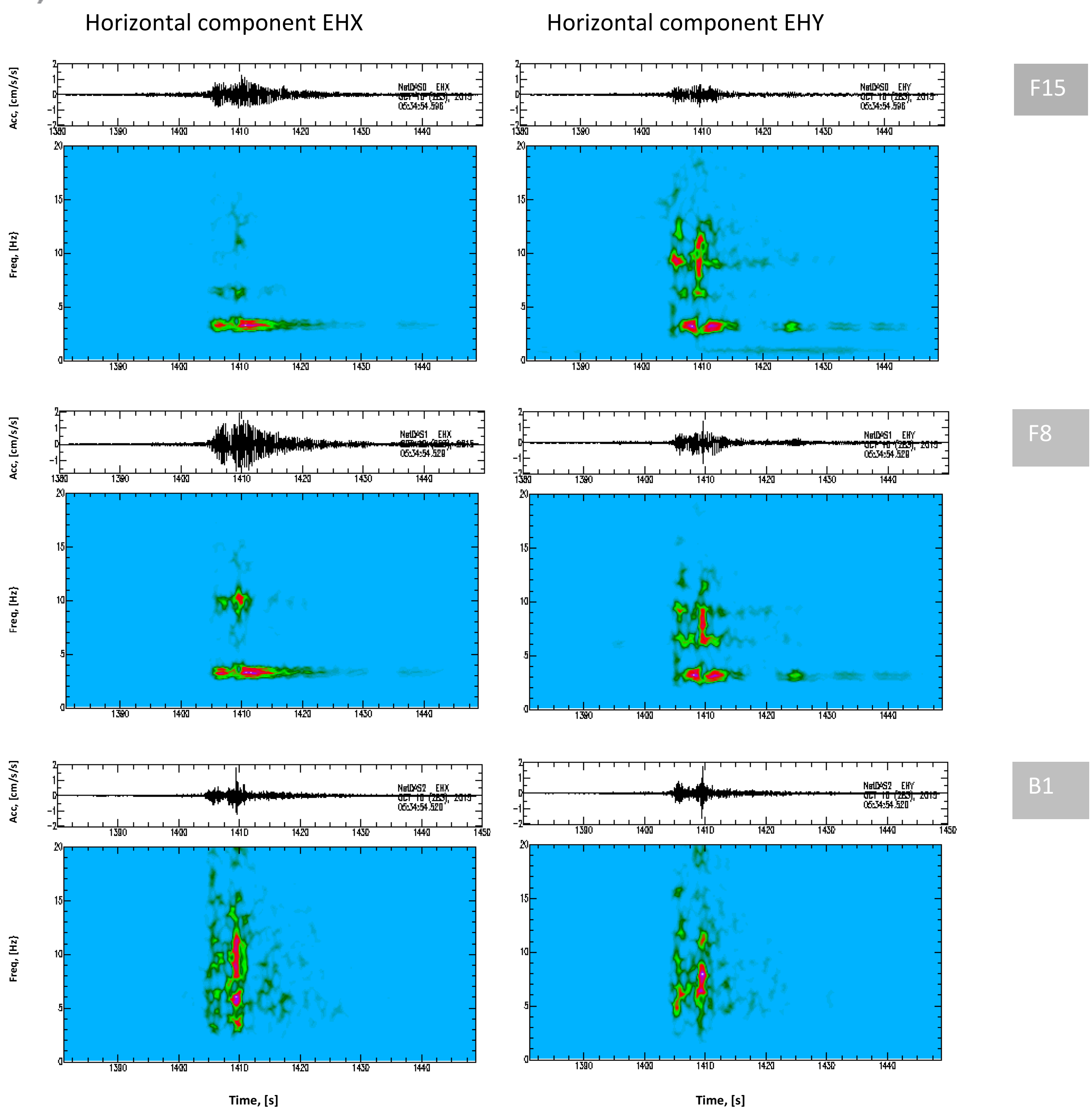

Fig.6 Acceleration records of the respective floors and its spectrogram (a) Horizontal EHX direction (b) Horizontal EHY direction, inside of the building “Khangarid”.

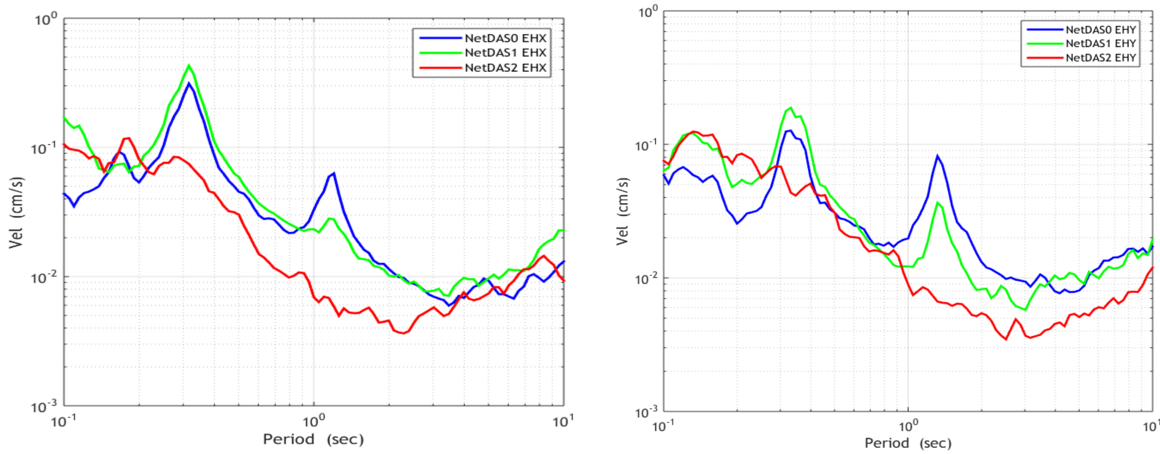

Fig.7 Velocity response spectra at respective floors. (a) Horizontal EHX direction (b) Horizontal EHY direction, inside of the building "Khangarid".

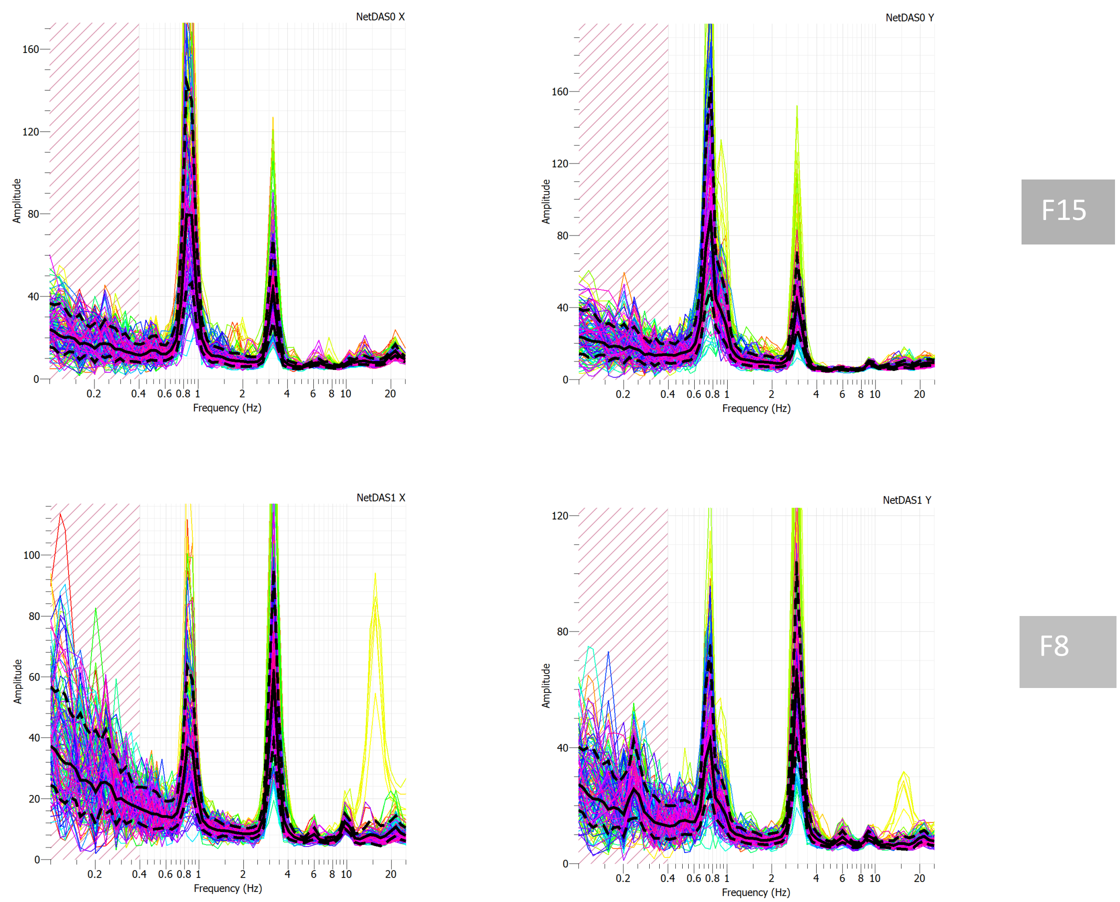

Fig.8 Microtremor measurement: Spectral mode information at the top-floor of 15th floor and at the med-floor of 8th, respectively. (a) Horizontal EHX direction (b) Horizontal EHY direction, inside of the building "Khangarid".

5. Concluding remarks

The strong motion network and SHM system has been continuing the installation and its operation in Ulaanbaatar capital city of Mongolia. The preliminary data archive is used to analysis of the sites of strong motion woth SHM system. The local event and microtremor records were used on spectral analysis as representing the buildings' response and modal shapes. In the future, the network enables the ground motion study in Ulaanbaatar basin as well as the research foundation source on Earthquake Engineering development in Mongolia.

6. Acknowledgement

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