# Seismic Studies from Small Aperture Accelerometric Network in Izmir Metropolitan City, Turkey

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***Abstract***— **This study deals with the results obtained from IzmirNet local strong-motion network installed in Izmir metropolitan city. Data were interpreted in terms of engineering seismology and earthquake engineering, correlation of noise using accelerometric array, seismological and seismotectonics studies. Site characteristics reveal an amplification factor equal or greater than 6.0 for a dominant frequency interval between 0.6 – 1.5 Hz on alluvial deposits observed mostly around the Izmir Gulf. Bigger frequencies and less amplifications were also detected for limestones and andesitic volcanic units. Recent study about cross-correlation of noise exposes underground velocity structure by using station-pairs methods. Low group velocities present at the east of the gulf where thick Quaternary-aged deposits exhibit over there. City was under high seismic risk according to the locations of recorded events by IzmirNet. Izmir, Orhanli-Tuzla and Seferihisar faults are candidate to produce a destructive earthquake in the future according to the present seismic activity and focal mechanisms solutions. Stress tensor study illuminates E-W aligned faulting under the N-S extension regime.**

***Keywords— IzmirNet; accelerometer; site properties; seismology***

## I. INTRODUCTION

Aegean region of Turkey is located at the western extremities of the country, and influenced the Aegean Extension Region (AER) which is one of the most seismically active and rapidly prolongated areas of the Eastern Mediterranean region. Two principal tectonic features play important role in the neotectonic context of the AER. First one is the Hellenic Subduction Zone at the SW of Turkey. Second one is dextral North Anatolian Fault (NAF) zone in the North. Izmir is the capital of the Aegean region of Turkey, and one of the most populated (with its more than 3.5 million inhabitants), and industrialized city of the country. Seismic activities are high due to the different type of active faulting systems which produce moderate type of earthquakes. Lifeline systems in city are also located very close to the active faults. Whether geology reveals complex distribution, most of the (industrial and populated) settlements are located on Quaternary alluvial deposits around the Gulf of Izmir. Other prominent units are Miocene-aged sandstones, mudstones, andesitic volcanic, and Paleocene limestones (Figure 1).

A small aperture local accelerometric array, IzmirNet, was installed in 2008 [1] with a cooperative initiation between Dokuz Eylul University (DEU) in Izmir, and the Prime Ministry Disaster and Emergency Management Presidency (AFAD) in Ankara. Primary goal of the project was to acquire strong ground motion data in order to understand the propagation and site characteristics of Quaternary sediments that underlay the Izmir metropolitan area, and are thought to produce large site amplification and seismic hazard. These data were complement with geotechnical laboratory data to characterize the properties of the soils underlying the city in order to design appropriate earthquake-resistant structures for the region. IzmirNet is also first step to develop a "Rapid Response and Damage Prediction System" for Metropolitan residential area in the future where near-real-time strong ground motion records are used to compute ground shaking maps showing the area most strongly affected by earthquake. All accelerographs of IzmirNet are free-field and equipped with three-component Guralp CMG-5TD built-in data acquisition systems. Technical details of the array were given in [1].

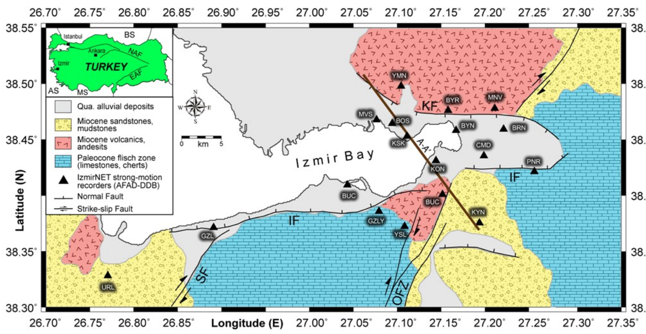


Figure 1. Location of IzmirNet array (filled triangles) on geology of Izmir [2]. **IF**: Izmir Fault, **KF**: Karsiyaka Fault, **OFZ**: Orhanli Fault Zone, **SF**: Seferihisar Fault (Turkey inset; **AS**: Aegean Sea, **BS**: Black Sea, **EAF**: East Anatolian Fault, **MS**: Mediterranean Sea, **NAF**: North Anatolian Fault). Thick line is the location of A-A' Profile in Figure 6).

## II. ENGINEERING SEISMOLOGY

### *A. Atteuation Relationships*

We could be able to find to test the validity of present attenuation relationship with measured peak ground acceleration (pga) by IzmirNet. A sample result was shown in Figure 2 according to the Turkish Earthquake Code (TDY) and

Eurocode-8 for an event occurred on June 20, 2009 (Mw=4.9). This study was repeated for several events on different soil types. We detected that Sadigh equation is most appropriate for our local array. It should be also noted that all limitations (min magnitude level, soil type, faulting, min and max distance interval) were carefully investigated for each event and taken into consideration during the study. Since there were no strong quakes (Mw>6.0), we could not compare some conventional theoretical curves with measured peak accelerations by IzmirNet. Once happens, this will be done for all soil types and different distances.

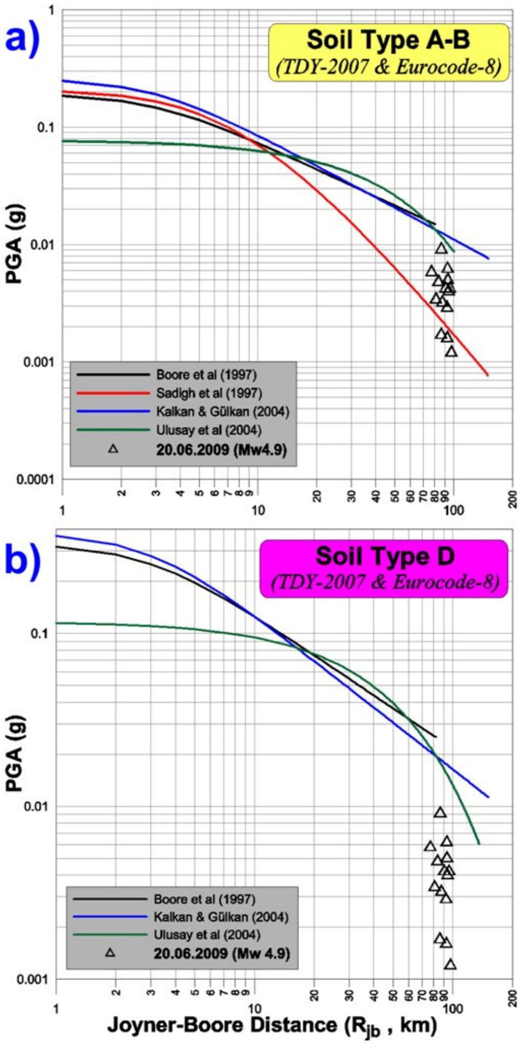


Figure 2. Excel otomatization for different type of attenuation relationship after a magnitude Mw=4.9 occurred in a distance ~90 km far on June 20, 2009 [3]. A) Attenuation distribution with distance was shown according to Turkish Earthquake Code (TDY) and Eurocode-8 for; a) soil type A&B, and b) soil type D.

*B. Site Characteristics*

Site characteristics of Quaternary and Neogene aged young sediments represented by accelerometric array, were principal goal of the study. Effects of local soil conditions on the earthquake waves have been investigated at 16 stations. We have used both the Horizontal-to-Vertical (H/V) spectral ratio and Standard Spectral Ratio (SSR) methods to determine soil amplifications. H/V examples for dominant site periods and spectral amplifications were given in Figure 3 and 4, respectively.

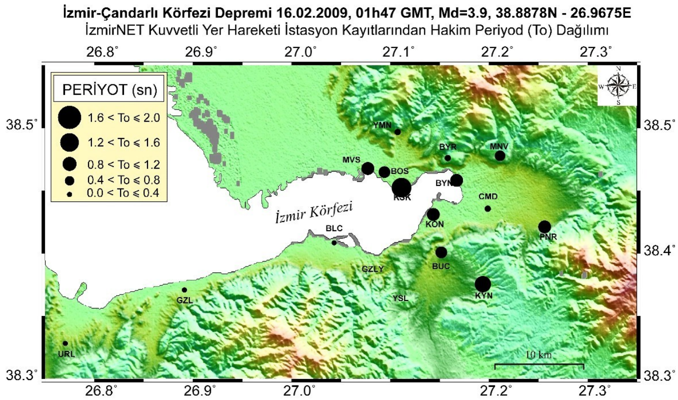


Figure 3. Distribution of different dominant periods (To) after an earthquake occurred in northern part of the study area on February 16, 2009 (01h47 GMT) with a magnitude Md=3.9. Geologic unit under the KSK station location (~27.1ºE, 38.45ºN) showed peak period during the event.

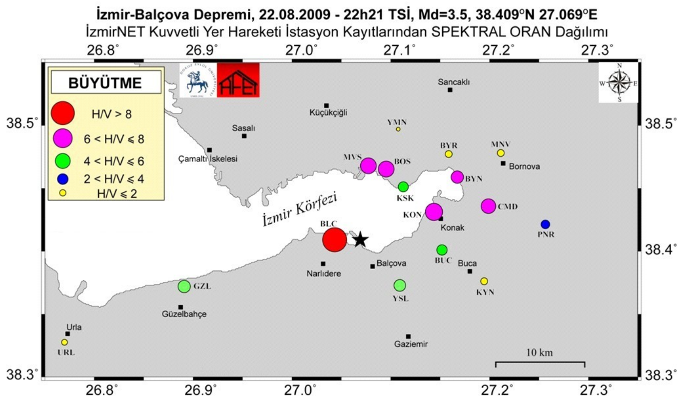


Figure 4. Distribution of H/V Spectral Ratio after an earthquake occurred in the southern sea cost of Izmir Bay (filled star) near Balcova settlement on August 22, 2009 (19h21 GMT) with a magnitude Md=3.5. Peak spectral ratios are observed on alluvial deposits around the Izmir Bay.

Sediment deposits in the northern and eastern part of Izmir Bay generally show high site periods and H/V spectral amplifications. Results also indicate that the local soil effects can considerably change with the earthquake arrived to station from closest directions (see BLC station location in Figure 4). Site effects are also investigated with the SSR method using the ground motion recordings from 10 earthquakes where occurred in different directions around IzmirNet. Examples from BYN, MVS (soft soil) and BYR (rock) stations were given in Figure 5. Overall, the SSR and H/V results are in line and show an amplification factor of 10 near 0.8 Hz. Similar SSR amplification value was also detected at 1.0 Hz fundamental frequency for MVS station (special site and potentially liquefiable peat according to the NEHRP classification). H/V peak frequency could not be well represented by a clear peak due to the wide perturbation for the

MVS curve lower than 1.0 Hz. The volcanic andesitic unit which is represented by BYR station, did not show amplification and fundamental frequency.

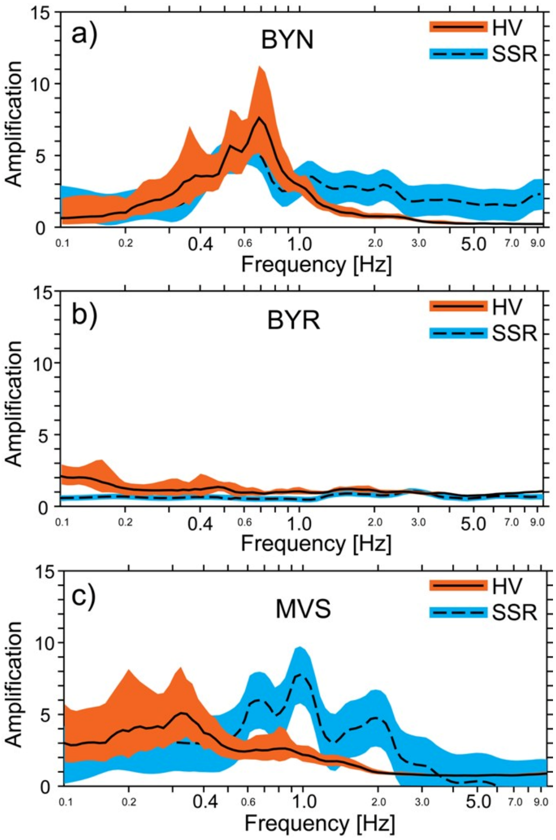


Figure 5. Distribution of H/V Spectral Ratio after an earthquake occurred in the southern sea cost of Izmir Bay (filled star) near Balcova settlement on August 22, 2009 (19h21 GMT) with a magnitude Md=3.5. Peak spectral ratios are observed on alluvial deposits around the Izmir Bay [4].

The agreement between the results of the two methods for all station locations is good in general. Therefore, the SSR method has important advantages in determining the local soil effects (amplification including fundamental frequency).

Vertical cross-section along A-A' profile (location in Figure 1) for the results obtained from SSR method, can be seen in Figure 6. Vertical (elevation) and horizontal distances are scaled in the figure. While the stations located on soft soil (such as KON, KSK, BOS and MVS) show high amplification around 5-10 factor, limestones or volcanic andesitic layers represented by KYN and YMN stations do not exhibit significant values. The BUC station, located at the top of hill, slightly indicates an amplification factor of 5.0 near 1.7 Hz.

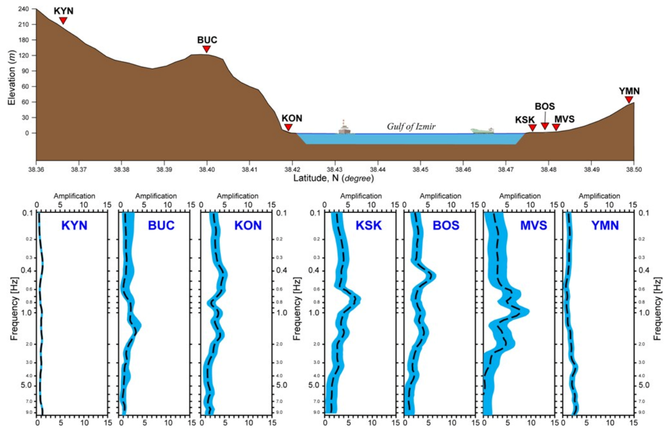


Figure 6. Amplification distribution of H/V Spectral Ratio after an earthquake occurred in the southern sea cost of Izmir Bay (filled star) near Balcova on August 22, 2009 (19h21 GMT) with a magnitude Md=3.5. Peak spectral ratios are observed on alluvial deposits around the Izmir Bay [5].

The reason of possible amplification in BUC station is still under investigation. But as the first step and tasking the mean of 10 events, this phenomenon might be explained by topography effect as already reported in various study for a destructive earthquake.

## III. CORRELATION OF NOISE

Whether principal aim of IzmirNet is to reveal site characteristics of station location, we also benefited continuous data recordings to investigate underground velocity structure of the city by using station pair method [6] In practice, it is always not so easy to find broad spaces in the densely populated areas such as Metropolitan city of Izmir for applying SPAC geometry, establishing long profile, obtaining acceptable natural ambient noise which does not contain cultural noise in the region that represents deeper structures. The method gives economic, rapid and precise results. An example of 4 stations pairs is given in Figure 7.

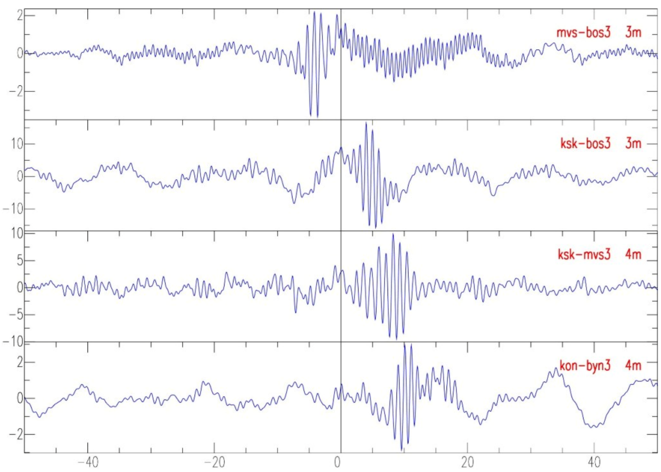


Figure 7. Traveltime-distance plot of cross-correlated traces. The group velocities are measured for station pairs during 3 or 4 months stacked data

Stacked noise recordings with 100 Hz frequency sampling at a distance between 1.6 km (for MVS-BOS) and 3.6 km (for KON-BYN) have been resulted in different filtering. After several trial, 0.4 - 2.2 Hz band-pass filtering was used to extract the surface wave group velocities (Figure 8). We detected higher group velocities in BYR-KSK station pairs. BYR was located on andesitic volcanic (rock) units. Lower group velocities are for KON-KSK and BUC-KON station pairs which represent deep alluvial deposits. We also investigated group velocity changes with periods (Figure 9).

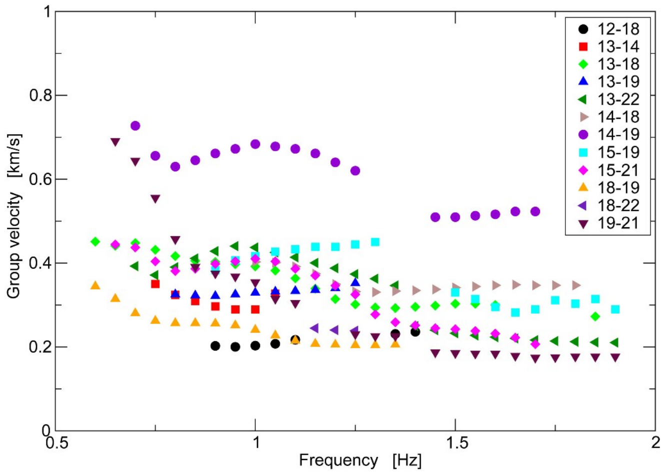


Figure 8. Distribution of group velocities versus frequencies. Higher velocities are for BYR-KSK station pair.

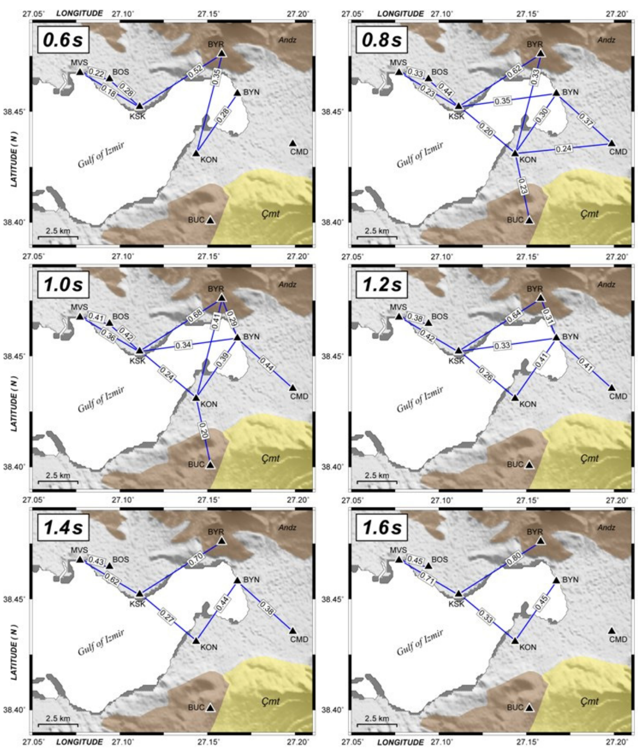


Figure 9. Group velocity distribution versus period [7].

We could not well determined changes of velocities in different periods for all station pairs. But as initial result, they increase while periods increase as expected and indicated deeper part of the shallow earth crust.

## IV. SEISMOTECTONICS

### A. Seismology

Regular location analysis using IzmirNet, have been performing in seismology lab of DEU for three years. Distribution of located earthquakes have been given in Figure 10. Some clusters can be easily seen on IF (south of Izmir Bay), on line trending NW-SE at outer gulf (26.75E-38.55N). Sigacik Bay (26.70E-38.20N) activity also targets the city.

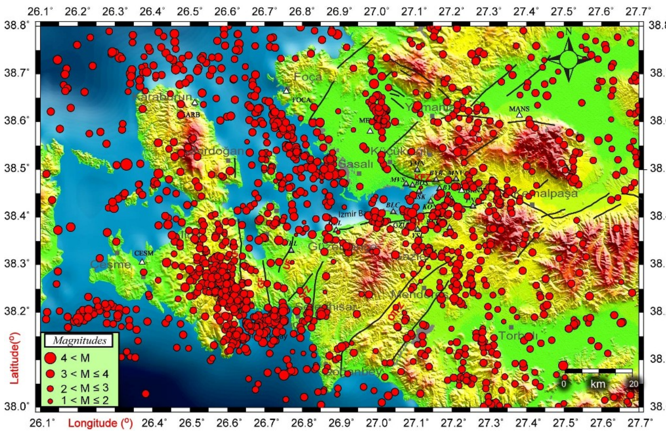


Figure 10. Distribution of 3 years located events using by IzmirNet array [8].

Most of the located events are concentrated at the upper part of the earth crust with equal or below to 15 km (Figure 11). Depths of the events occurred in outer gulf, reach up to 20 km. Same result was also valid for the events at the east of Izmir Bay.

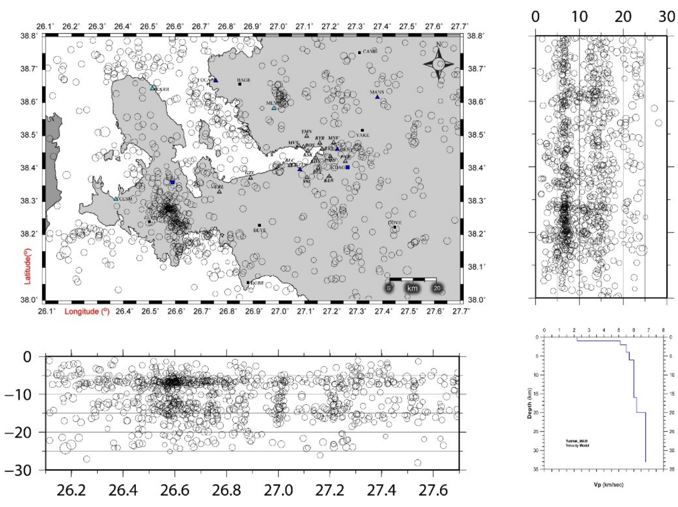


Figure 11. Depths of the located events according to longitude and latitude. 1-D velocity structure is given in the lower-right corner [8].

### B. *Focal Mechanisms*

P-wave first motion focal mechanisms were carefully performed during the study (Figure 12). Fault plane solutions of located events indicate dominant normal faults, in general, with minor strike-slip components. But, we also detected 4 events with dominant strike-slips (with minor normal or reverse components) as seen for the events numbered with 01, 18, 21, 22, and one event with dominant reverse faulting with minor strike-slip. These are expected revealing the heterogeneity of the earth crust.

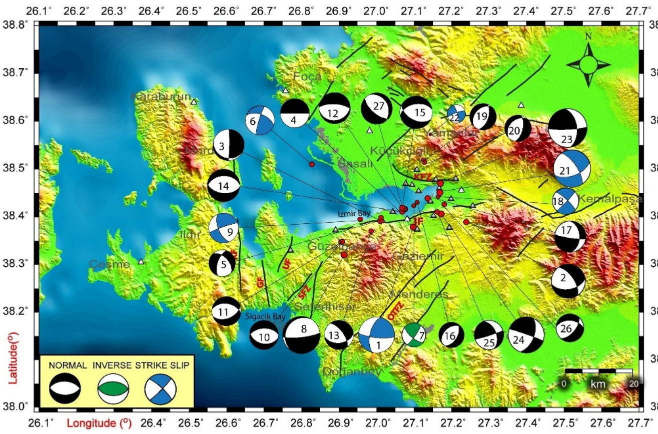


Figure 12. Focal mechanisms of 27 events obtained by using IzmirNet local array [8].

### C. *Stress Tensor*

After completed focal mechanisms study, we decided to investigate stress regime of the study areas (Figure 13).

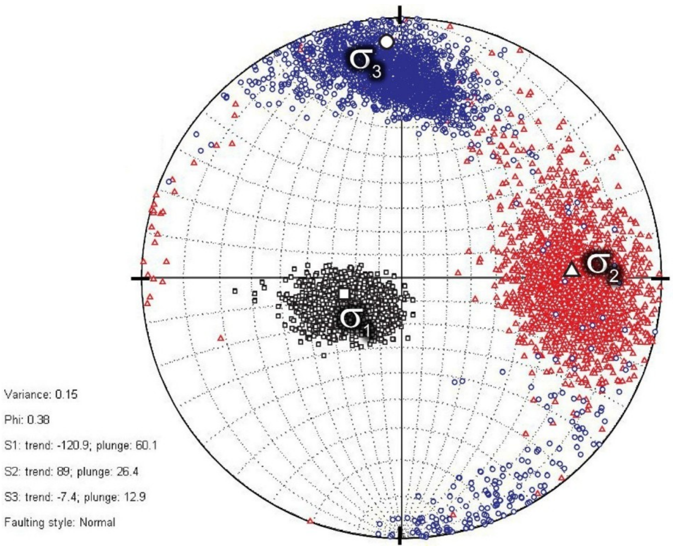


Figure 13. Stress regime of the study area revealed by IzmirNet [8].

For this purpose, we used stress tensor analysis. Maximum principal stress axis ($\sigma_1$) was found near the horizontal (towards to center) while minimum principal stress axis ($\sigma_3$) was as vertical (towards to the Northern part of outer circle). This result indicate that study area is under N-S extension regime.

## V. CONCLUSIONS

Small aperture strong-motion array can be used to describe not only for soil characteristics but also seismotectonics studies. This research is a good example to show all available studies using by IzmirNet local accelerometric network. In general, the systematic survey of the site response using both the SSR and H/V methods, has shown ground amplification at lower frequencies exists in Izmir metropolitan city.

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