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EFFECT OF TRENCH BARRIER ON FREE FIELD MOTION DUE TO THE TRAIN AND HIGHSPEED TRAIN PASSAGES

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Abstract

Railway transport is one the most preferable way of commuting from/to urban centers. Although it has several advantages on other ways of transportation such as its cost effectiveness, energy efficiency, safety and least dependency to weather conditions, there is also a disadvantage by inducing discomfort vibration to the surrounding area especially in the urban centers. In this study, a trench barrier along the track line has been used in order to reduce the vibration induced by trains and high-speed trains. A series of field testing has been carried out. The vibration levels from the freight/passenger trains and high speed trains passages were measured in three directions up to the 40m from the track lines. The average Vs30 value was 200m/s and the speed of the high-speed train was 250km/h at the site. As a vibration mitigation measure an excavated trench barrier has been used along the track line. The vibration levels with and without trench barrier have been compared for the freight/passenger trains and high speed trains passages. The obtained records have been analyzed both in time and frequency domains. The results showed that the trench barrier effectively reduces the vibration level.

Keywords: Vibration motion, Train Vibration, Ground vibration, Railway Track, Earthquake Engineering.

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1 INTRODUCTION

High speed trains are planned with a maximum of 250–300 km/h speed and a maximum of 22.5 ton force axle loads. Railway platform which is vibrated with higher frequency dynamic loads induced by high speed train cars transfer these vibrations energies to surrounding ground and close by structures are effected by them. Strong ground motion not only can give damage to the nearby buildings and their footings but also affect the human comfort by undesired vibrations. Thus for an effective protection of railway platforms, nearby buildings, and mitigation of strong vibrations optimum in-situ isolation material needs to be determined by well understanding the wave propagation problems depending on soils conditions. Extensive in-situ research are still required for both recent ongoing construction projects in soft soil deposits and for planned construction projects on highly populated areas. High speed train transportation is recently initiated in Turkey and researches are focused on platform vibrations and reduction of noise contamination, there is a gap in the research of dynamic behavior of structures considering soil-structure interaction effect and wave propagation in soft soil. With this study this gap is planned to be fulfilled. Most of the vibration energy is transferred by Rayleigh Surface waves. Dynamic stresses and deflections will be amplified with Resonance when the critical velocity which can cause maximum deflection railway sub-structure is equal to the velocity of Rayleigh waves. In this situation, a precaution as constructing the sub-structure of railway as rigid slab without ballast instead of constructing the substructure using ballast in alluvial soil conditions can be taken to reduce such affects due to resonance. Moreover, a civil engineering solution for existing buildings can be offered as constructing elastic, elasto-plastic or rigid isolation structures perpendicular to the wave front direction, underneath with an optimum depth or around the building to be protected for overcoming vibration problems. Thus, wave propagations of vibrations produced by dynamic sources in the soil is prevented to reach structures by the reduction affect created by saturating reflecting or refracting waves. Active isolation is defined when wave barrier is constructed near to vibration source while passive isolation is defined when it is constructed near to the structure to be protected. The most important factors effecting the performance of the isolation barriers are location, dimension and the material density of the barrier that defines the impedance contrast for this type of isolation barrier constructed in soil.

The aim of this study is to investigate the effect of vibrations from normal-speed/high-speed, local/regional and freight/passenger trains on the surrounding fields and ways of vibration mitigations through the field recordings and analysis.

2 RECENT STUDIES ON ENVIRONMENTAL VIBRATIONS

With the development of technology, the increase in living standards and the spread of urbanization constitute a demand for safer and quality life in the society. Regardless of ground motion caused by earthquakes, it is important to examine the environmental vibrations generated by the bursts of the work machines and the increasing traffic load. Bata, 1971; Massarsch 1993, 2004 and Xia etal. 2007 carried out studies according to subject.

In Italy, depending on the developed industry, the growth of urbanization created a demand for transportation. Crispino and Dapuzzo (2001) examined the transportation sourced vibration problems to protect historical buildings and cultural heritage.

Investigation of the propagation mechanism of vibrations caused by human sourced vibrations at high frequencies and their propagation characteristics under soft soil conditions; studies such as the development of vibration isolation tools, and human comfort have also been important research subjects (TUBITAK 1001 project 217M427, 2018).

3 METHODOLOGY

In this study, field work was performed to measure the vibrations produced by railway traffic to the surrounding area. By taking into account local soil conditions where the Ankara-Istanbul high-speed railway line runs through two directions, vibration measurements were performed to evaluate the free ground motion generated by the repeated train passes. The test location has been chosen near to Arifiye station of Istanbul and Ankara high-speed railway line which has a total length of 533 km as shown on the map in Figure 1. This place was chosen because of its weak soil condition and high speed of the train with over 200km/h. Throughout the study, normal-speed/high-speed, passenger/freight train transitions were monitored repeatedly. The ground conditions of the environment are in poor condition with Vs30 <300m/sn. The test location is within the university social facility with a guest house located just 8-10 m away from the railway line as shown in the Figure 1 right side.

3.1 Location

The line between Köseköy and Pamukova is marked with yellow and shown in the Figure 1 left side. The building where the recording devices are placed around is enclosed in the rectangle and marked in the Figure 1 right side.

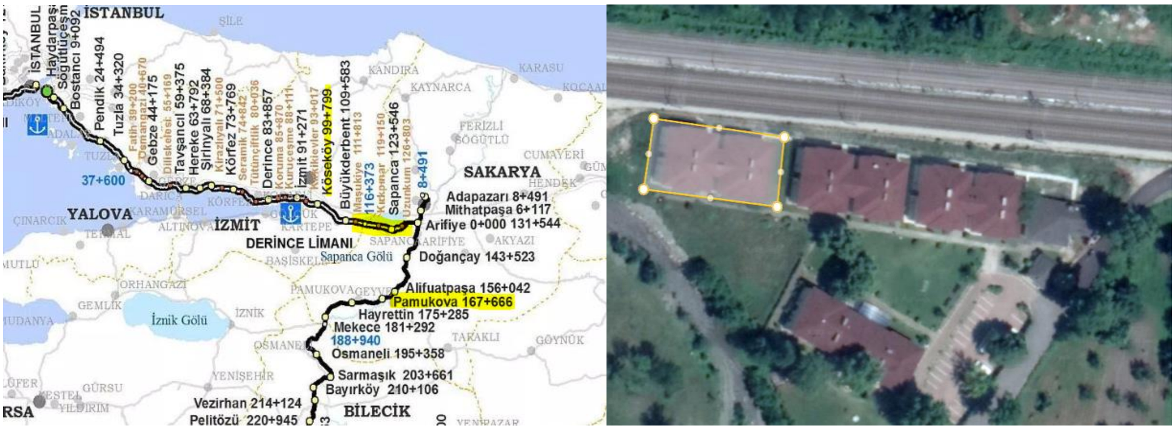

Figure 1 Location of railway line (left) and field (right)

Figure 2 Field view and accelerometer locations

3.2 The Test Site and Situation Plan

The testing instrumentation plan can be seen below in Figure 3. There are 4 separate railway lines. They are divided in accordance to the types of trains. The accelerometers have a fixed distance of 7 m from the line; four of them placed to left side of the building to observe free field motion without any mitigation measure, another four of them located on the right side of the building to observe the diminished field motion with a mitigation measure of trench barrier. 14 accelerometers in total placed for observation. Ten of them for soil motions, the other four of them placed in the building for structural monitoring observations. In this study only records from 8 stations located on the free field at the left and right side of the building w/o trench barrier respectively have been studied.

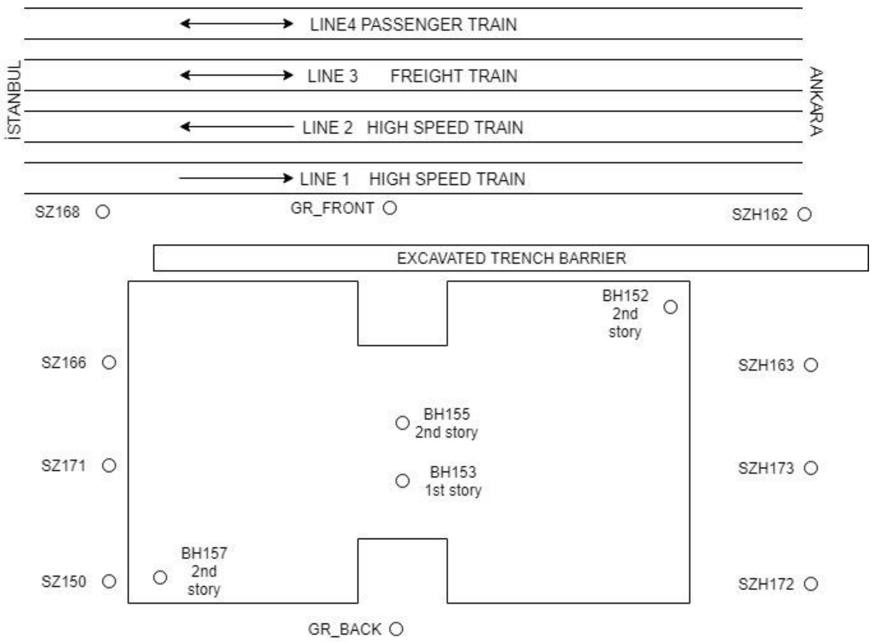

Figure 3 The testing instrumentation plan

3.3 General Info of Train Records

As a result of the observation of repeated train passes, a total of 15 train vibrations were recorded and evaluated. The number of trains passes records depending on the type of trains are shown in the table below.

Table 1 Repeated Train Passes

Direction	High-speed Train	Passenger Train	Freight Train	Total
Istanbul	4	1	3	8
Ankara	4	2	1	7
Total	8	3	4	15

3.4 Time Domain Analysis

The recorded motions were first analyzed in the time domain. The raw motions were filtered and baseline corrected. Butterworth 4^{th} order bandpass filter was used. The frequency range determined between 10 Hz to 100 Hz. Acceleration - velocity time graphs were drawn for three different directions and peak acceleration and peak velocity values were extracted.

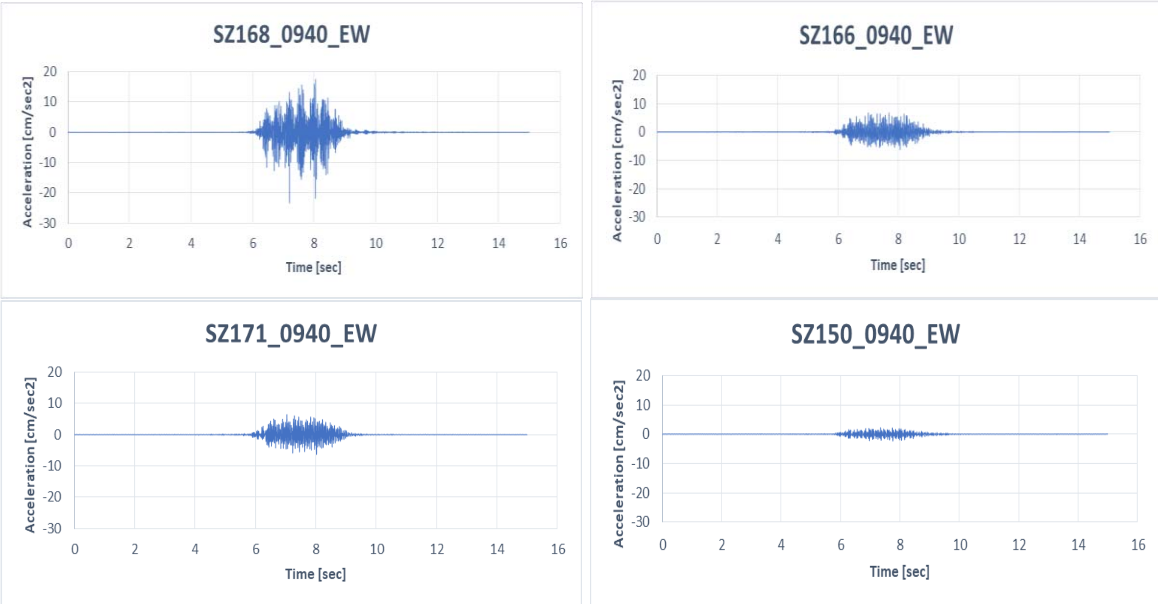

Figure 4 Acceleration Time graphs of high-speed train to Ankara direction (free field motion)

Table 2 Comparison of PGA values of High – speed trains through Ankara direction.

Accelerometers	Direction	Distance	Motion Type	0940 PGA	0940 PGA	1104 PGA	1104 PGA	1215 PGA	1215 PGA
				E-W	N-S	E-W	N-S	E-W	N-S
SZ168	Ankara	7	Free field	23.379	23.003	16.649	12.203	20.334	14.997
SZ166	Ankara	14	Free field	6.785	7.810	4.345	8.273	4.645	9.997
SZ171	Ankara	21	Free field	6.431	8.165	4.451	5.062	5.589	6.606
SZ150	Ankara	28	Free field	2.305	4.434	2.847	4.333	3.913	4.501
SZH163	Ankara	14	Ditched	3.080	6.349	2.272	5.021	2.522	4.614
SZH173	Ankara	21	Ditched	3.894	4.642	3.320	3.182	3.699	3.121
SZH172	Ankara	28	Ditched	1.863	3.118	1.327	1.716	1.333	2.014

The Acceleration-Time graphs of high-speed train Ankara direction vibration records on free field without trench barrier are shown in the Figure 4. It was observed that the maximum acceleration value decreased as it moved away from the railway line. And also comparison of free field and ditched motion with PGA values is demonstrated in Table 2. As it can be seen from the table, barrier effect shows reduction on PGA values compared with free field motion.

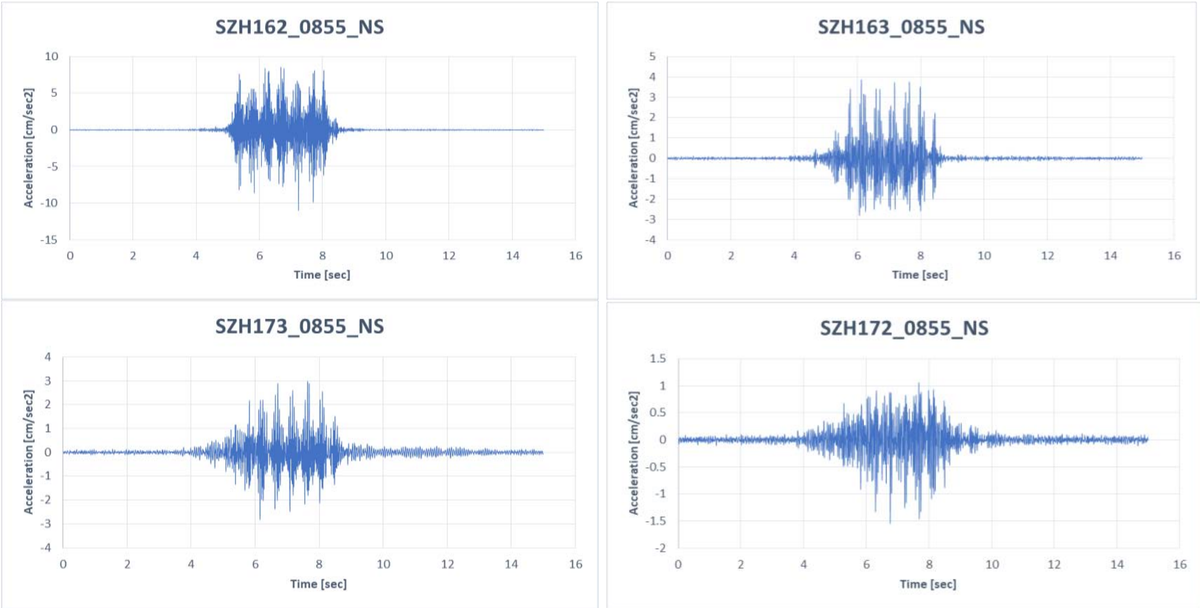

Figure 5 Acceleration Time graphs of high-speed train to Istanbul direction (barrier free field motion)

Table 3 Comparison of PGA values of High – speed trains through Istanbul direction.

Accelerometers	Direction	Distance	Motion Type	0855 PGA	0855 PGA	1011 PGA	1011 PGA	1118 PGA	1118 PGA
				E-W	N-S	E-W	N-S	E-W	N-S
SZ168	Istanbul	10	Free field	-	-	8.376	8.820	9.281	9.251
SZ166	Istanbul	17	Free field	6.142	7.651	6.000	8.538	6.625	9.856
SZ171	Istanbul	24	Free field	4.046	3.225	4.558	3.699	4.477	4.015
SZ150	Istanbul	31	Free field	2.384	4.736	2.644	3.751	2.790	3.428
SZH162	Istanbul	10	Ditched	4.266	8.554	-	-	-	-
SZH163	Istanbul	17	Ditched	2.147	3.864	2.236	3.537	2.485	3.587
SZH173	Istanbul	24	Ditched	3.209	2.967	3.314	2.671	3.696	2.494
SZH172	Istanbul	31	Ditched	1.148	1.035	1.059	1.178	1.333	1.343

In addition, second track line vibration motions (Istanbul direction) were recorded to observe the effects of the distance on the train vibrations as shown in the Figure 5. The results showed that distance of track lines and PGA values are directly proportional.

Furthermore, directional effect of train vibration is obvious and can be seen in Table 2 and Table 3. The perpendicular (N-S) direction of train vibration has more impact than the parallel (E-W) direction regarding to PGA values.

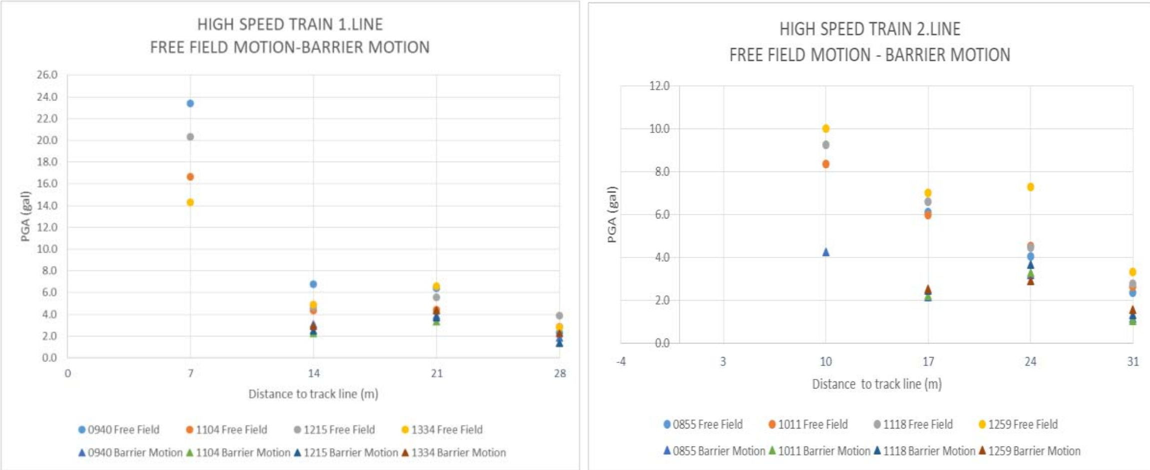

Figure 6 PGA graphs of Ankara (left) and Istanbul (right)

Parallel (E-W) direction of PGA graphs of high speed trains seen above in the Figure 6. Free field motion have been represented by circles and diminished barrier motion have been represented by triangles. As it can be seen from the Figure, triangles located below level of the graph. Maximum peak acceleration for free field is about 24 cm/s^2 and for barrier motion, peak value is about 4 cm/s^2. Therefore it can be said that barrier effected PGA directly. The Figure 7 shows the perpendicular (N-S) direction peak acceleration graphs of high speed trains. Barrier vibration records for perpendicular (N-S) direction have also been decreased compared to free field motion. Maximum peak value for the free field is about 28 cm/s^2 and for barrier motion, peak value is about 9 cm/s^2

Also comparison of the 1st line to 2nd line shows decreasing peak values in the Figure 6 and Figure 7. An amplification observed at the third alignment, which might be based on the soil effect of the field.

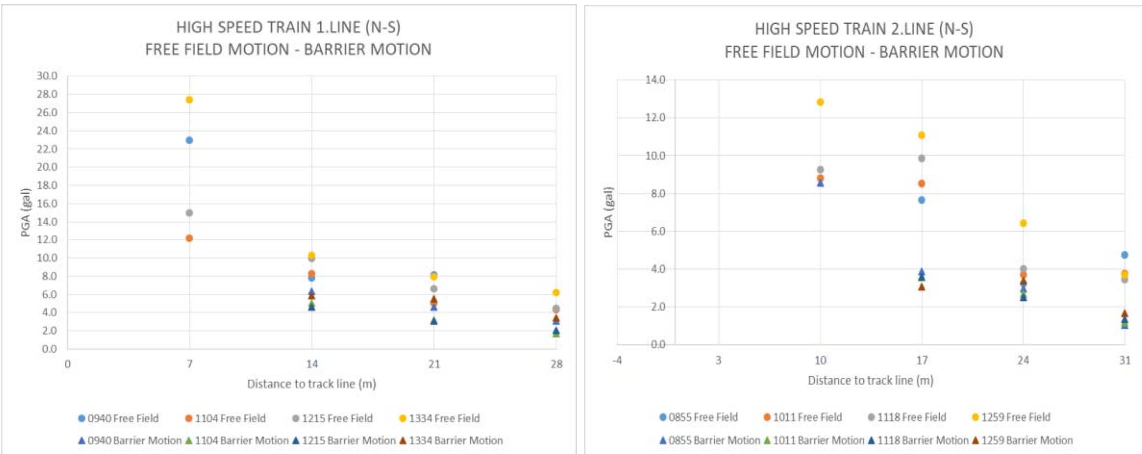

Figure 7 PGA graphs of Ankara (left) and Istanbul (right)

3.5 Frequency Domain Analysis

The dominant frequencies for the free field and barrier motions reaches to 80 Hz – 90 Hz as it approaches the train line, but decreases about to 20 Hz – 45 Hz as it moves away from the line as shown in the Figure 8 and Figure 9, respectively. As it can be seen from the Fourier Amplitude Spectrum graphs, the barrier has not changed the frequency content of the ground motion. The higher frequencies of 80Hz-90Hz can be observed at the recording stations near the track lines, however the dominant frequencies reduce to 20Hz and 45Hz in the distant recording stations.

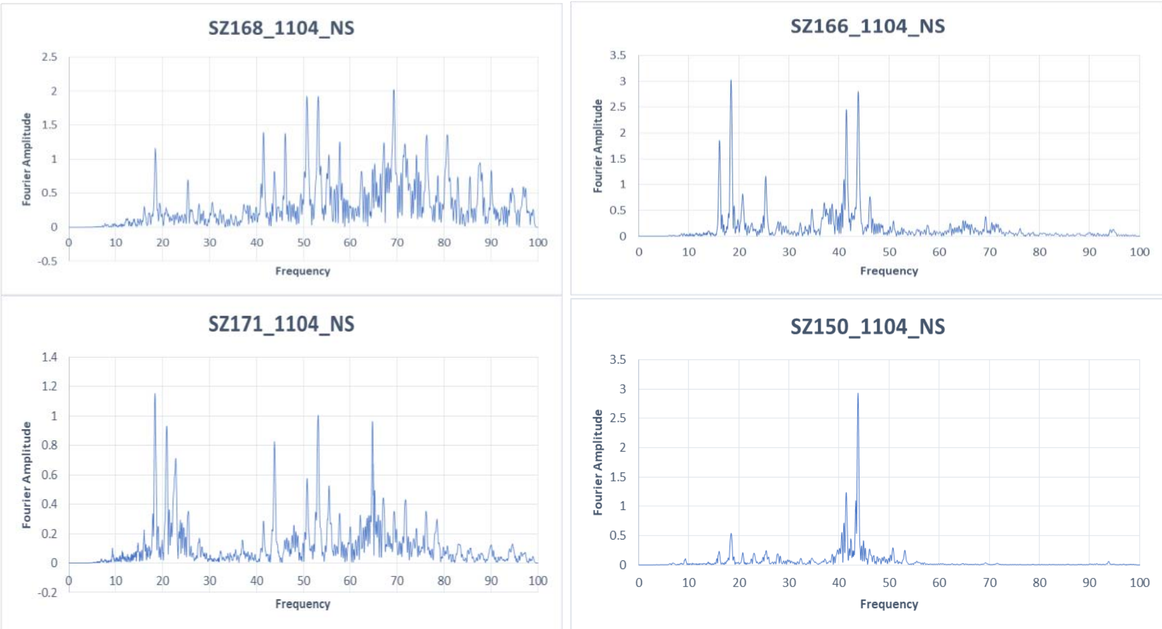

Figure 8 Free Field Motion FAS

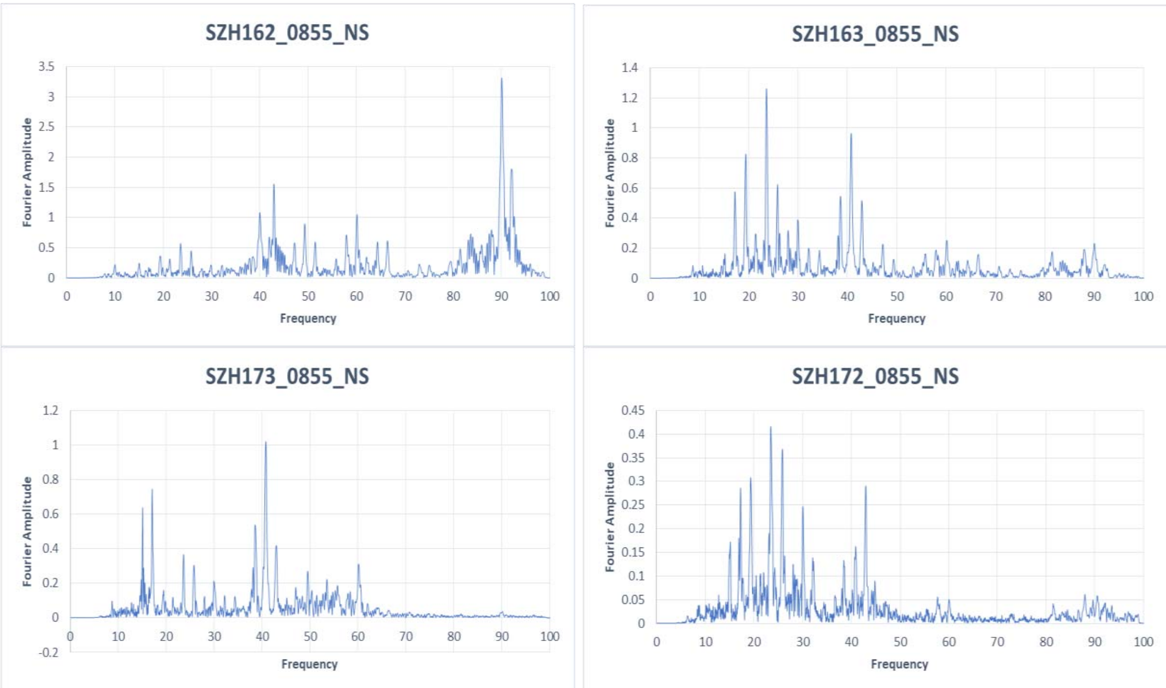

Figure 9 FAS of Barrier Motion

4 CONCLUSIONS

The high-speed train transportation is recently initiated in Turkey and it is planned to construct ten thousand km high-speed train line by the year 2023. The increase in the high-speed railway lines especially in urban environments has brought the consideration of the vibration effects of train lines on the surrounding residential districts. In this study, several field tests have been achieved in order to observe the vibration effects of normal-speed/high-speed, local/regional and freight/passenger trains. A trench barrier has been used as a vibration mitigation measure. The recordings on the free field w/o trench barrier have been analyzed. The following observations have been extracted from the analysis results.

- Peak acceleration and peak velocity values decreased with the existence of the trench barrier.
- The vibrations on the perpendicular (N-S) direction to train line has more impact than parallel (E-W) direction regarding to PGA values.
- The peak acceleration and peak velocity values decreased with the increasing distance from the track lines.
- The higher frequencies 80Hz-90Hz have been observed near the track lines. The dominant frequencies have reduced to 20Hz – 45 Hz with the increasing distance from the railway lines.
- The trench barrier did not show any important effect on the frequency content of the recorded train vibrations.

This paper studies the train vibration records and its effects on the surrounding area. The effect of the trench barrier as a mitigation measure has been also studied. The effect of the train vibrations on the building structures and its mitigation measures will be studied further.

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