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A Study on the Examination of the Geologic Structure in terms of Rail Transportation

Emre Kuşkapan[1]*, ÖmerLütfü Aydın[2] and Muhammed Yasin Çodur[1]

[1]Erzurum Technical University, Faculty of Engineering and Architecture, Civil Engineering Department, 25200, Erzurum, Turkey

[2]Erzurum Metropolitan Municipality, Yakutiye, 25200, Erzurum, Turkey

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Rail systems have an important place among the types of transportation. Although it was preferred for intercity transportation in the past, but now-a-days it is frequently preferred in urban roads. Some rail system structures move from the ground surface, while others move under the ground. Various geotechnical researches have been carried out for rail systems moving under the ground. However, for the rail vehicles moving on the ground surface are generally placed on the highway route, ground parameters are not taken into consideration. This situation can cause serious rail system accidents. This study has been conducted in Turkey's Erzurum drilling planned light rail system in terms of soil properties, it was evaluated by survey results of drilling borehole, microtremor, and multichannel analysis of surface waves (MASW). According to the results of this study, a part of the light rail system (LRS) route was found to be insufficient in terms of ground safety. For this reason, improvement in the ground or revision of the route has been suggested.

Keywords: Liquefaction, Microtremor, Rail system, Route suitability analysis, Transportation

Introduction

The geological structure has a very important place in transportation policies. Before a road or railway line is built in an area, the geological structure must be analyzed. Although this situation is taken into consideration most of the time, sufficient attention is not paid when building urban rail systems. Because most of the urban rail systems are built on the highway route.[1] In this case, it causes deformations on the ground over time resulting occurring of train accidents. In these accidents, serious loss of life and property can occur.[2]

There are many studies to examine the accidents that may occur in rail systems. Some of these studies examine the rail system technology, while others take into account the ground structure.[3] In these examinations, researchers try to analyze the accidents better by using various methods. Rail system technology has come a long way, especially thanks to the smart transportation systems and the development of technology.[4] Some of the newly built rail vehicles can even provide transportation without a driver. However, the ground structure can differ even at small distances. For this reason, accidents caused by the ground structure are frequently encountered even today. The underground water level of the ground, the parameters of the ground structure, and the type of the ground structure can affect this situation. Especially if there is a potential for liquefaction on the ground, settlements may occur on the ground over time.[5]

Various infrastructure analysis methods are carried out for the route through the rail systems pass, to examine the deformations that may occur in soils. In order to make an analysis, ground studies are used, which include information about soil structure, class, and properties. Thanks to these studies and tests that have helped over the time to determine parameters of soil performance. By applying various analytical methods to the determined parameters, comments can be made about the conditions under which the soil structure is suitable or not.[6]

Related Work

There are various studies examining geologic structure of rail transportation. Some of these studies are directly or indirectly related to the route of rail transportation. Jin *et al*. evaluated the Qinghai-Tibet highway and railway line in China in terms of ground conditions. Especially, they revealed the negative effects of wetland and frozen ground conditions on-road routes. In the results part, they mentioned the

*Author for Correspondence
E-mail: emre.kuskapan@erzurum.edu.tr

necessity of carrying out studies taking into account the climatic changes during road construction.[7] Zhao *et al*. examined the railway tunnels in terms of ground. It was mentioned that many accidents occurred due to the filling of water in the tunnels and the accumulation of sludge. In order to prevent this situation, advanced geological estimation methods have been used. Energy release and pressure relief technology, advanced injection technology and basic technical features have been proposed to avoid the mentioned problem.[8] Yıldırım and Bediroğlu of their study examined the planned railway routes between Erzincan-Trabzon in Turkey. Geographical information system (GIS) based network analysis and analytical hierarchy process (AHP) methods were applied in the route creation process. Thanks to these methods, cultural and historical structures and environmental integrity have been preserved. The new hybrid route reduced construction costs by about 12%.[(9)]

Existing studies in the literature generally made suggestions by examining the geological structure of an existing rail system line. Some studies have examined the route of the rail system to be built and made suggestions as an alternative. But sufficient ground studies were not taken into consideration for this. However, in this study, drilling borehole, microtremor and MASW data were used. In this way, the ground structure was discussed in detail. In this study, the suitability of the LRS route determined for Erzurum province in terms of physical ground parameters was analyzed. In Erzurum province, the ground survey studies created by the micro-zoning method were classified according to physical parameters. The LRS route was examined by survey results of methods, and the soil structure was evaluated. In the results obtained, it was determined that some points of the LRS route were problematic, and it was recommended to make a ground improvement or revise the route for these points. At points where the ground structure is not suitable, it has been suggested that the ground should be improved or the route should be revised considering the passenger demand.

Material Method

In the study, with the help of the geological-geotechnical survey data of the Erzurum province master development plan prepared in the area, it was aimed to determine the areas where geotechnical projects should be prepared by analyzing the LRS route.[10] The study is basically divided into six main parts. After the study area was defined, the parameters were defined and the data were analyzed. Then, the analysis of the data, the interpretation of the results, and the revision of the work route were made. These stages are briefly expressed in Fig. 1.

Study area

Erzurum is located in the northeastern part of Turkey. An important part of the study area is alluvium and in some parts, there is a slope debris structure. At the same time, the topographical slope varies as Erzurum is located on the skirts of Palandöken Mountain.[11] In addition to these situations, the groundwater level is quite high due to the climate structure, the snow melting in the winter months and the rainy summer months. In this context, the field studies and the results of the ground surveys obtained from these studies should be evaluated. The location and geological characteristics of Erzurum in the world are given in Fig. 2 below.[12] The route of the light rail system planned to be built in Erzurum province is shown in Fig. 3.

Accordingly, the planned rail system line is approximately 15 kilometers long and consists of 16 stops in total. Although the distance between the stops varies, the average is 1 kilometer. Also, a distance of 100 meters is reserved for each stop. Designed as a one-way line, this line starts moving from Station Square and passes through Erzurum Castle, City Center, Atatürk University, Yıldızkent, Yenişehir, Yunusemre Neighborhood and ends its movement again in Station Square.[13]

Field studies

In line with the geological data of the study area, to determine the lateral and vertical changes, engineering properties and physical and mechanical parameters of the units, a total of 2536 m long foundation drilling, 181 depths varying between 10 m and 20 m, determine the dynamic elasticity parameters, soil amplification. To determine the

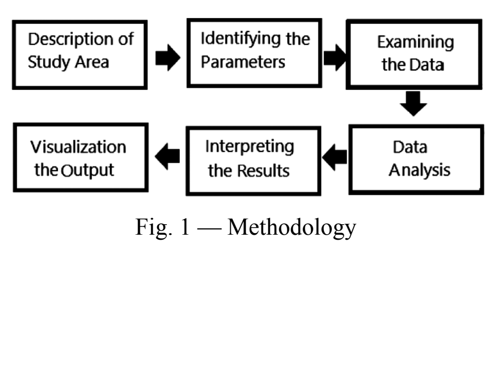

Fig. 1 — Methodology

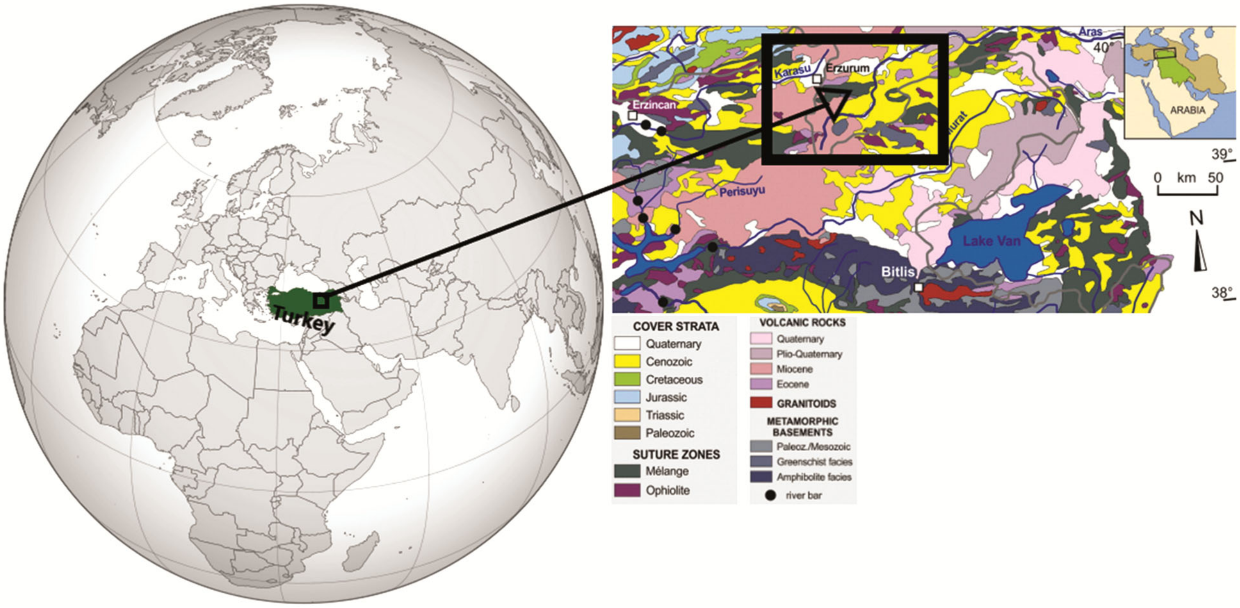

Fig. 2 — Geological map of Erzurum and its surrounding including the study area

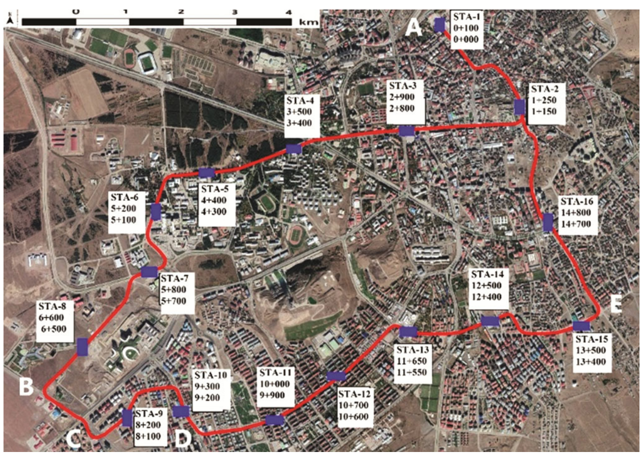

Fig. 3 — The LRS route map of Erzurum province

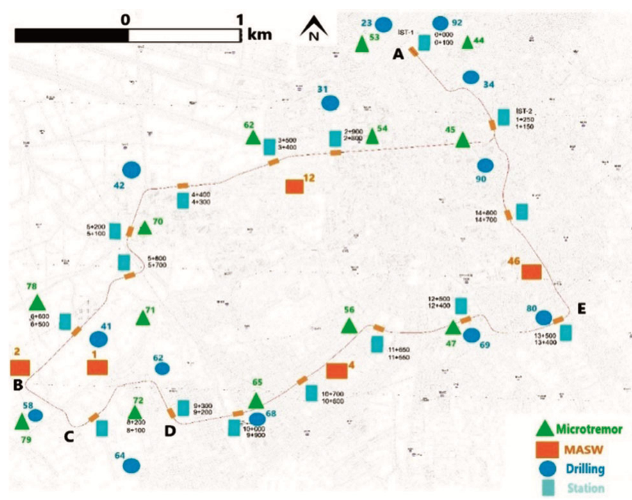

Fig. 4 — Locations of microtremor, borehole and MASW are located in areas close to the LRS route

ground dominance period, 150 microtremors, 62 MASW, 12 seismic refractions and 75 vertical electrical soundings (VES) were carried out. In the light of the studies carried out, 8 drillings, 13 microtremors, 5 MASW survey results were made on the LRS route. The locations of the on-site experimental studies are shown in Fig. 4.

MASW is an extremely beneficial technique for examining the shallow geological design and, in particular, the relative shear strength of subsurface components. By integrating density values for the local bedrock and overburden sediments it is possible to derive their shear modulus frequently referred to as dynamic ground stiffness.[14] Microtremor is a low amplitude (in the order of micrometres) ambient vibration of the ground caused by man-made or atmospheric disturbances. The phrase ambient vibrations are now favored to talk regarding this trend. Statement of microtremors may provide beneficial details on the dynamic attribute of the site for example the predominant period and amplitude. Microtremor findings are simple to execute, inexpensive and can be utilized to areas with low seismicity as well, hence, microtremor dimensions can be applied easily for seismic microzonation.[15] More comprehensive details on the shear wave velocity profile of the site can be acquired from microtremor array statement. Borehole drilling is performed to identify the environmental hygiene of the soil and to establish the structural quality of the building. The objective of the drilling must be established in advance.[16]

Groundwater level: There is continuous water intrusion into the plain due to the continuous feeding with underground and surface water from the mountains and hills surrounding the Erzurum Plain and the Karasu Stream passing through the basin. For this reason, the groundwater level in the plain is located near the surface. In the study area, groundwater is observed at levels close to the surface in general of the wells drilled in the Erzurum Plain. On the mountain slopes and slopes, the groundwater level was found deeper.[17] By making a groundwater level distribution map of the study area, it has been tried to obtain information about the direction of water flow and the places of water collection. The groundwater level in the city center of Erzurum varies between 0.50 m and 13.00 m.

Soils bearing capacity: Bearing strength refers to the resistance of the ground under the foundation against interaction under any load, that is, sliding and collapse. The bearing power of ground is the depth of effect; The building to be built on it is accepted as approximately twice the width of the foundation.[18] The SPT test was carried out in the old and current alluvial units in the study area, as well as in the foundation drilling studies in the slope debris and alluvial fan deposits. Bearing strength values in the work area is between 0.37 and 3.98 kg /cm^2.

Results and Discussion

The values of Vs_{30}, the dominant vibration period and the ground amplification value (Av) for the study area are important to determine the condition of the ground structure. Maps for these values are shown in Fig. 5.

In the Vs_{30} map prepared for the area, it is observed that the Vs_{30} velocity is between 180–220 m/s at point A where the route plan starts, and between 280–300 m/s at points B and C. When seismic velocities are examined, it is observed that it moves with low velocities at points A, B and C.

When the site dominant vibration period is examined, high periods are observed showing 0.80 s at the B point and 0.5 s at the C point. It points to various problems in one or more of the physical parameters of this area. However, the ground dominant vibration period in the D-E axis shows low oscillations in the range of 0.05 – 0.25 s (Fig. 6). These low values indicate that the physical parameters of the soils in this region have higher strength than other points.[19]

When the Av map is examined, the ground amplification value in the range of 3.6 – 3.8 is observed at the B point, which means that the physical parameters of the ground should be examined. When the D - E axis is examined, the ground amplification value is in the range of 1 – 1.4 (Fig. 7).

The basis of the study is based on the Geological Geotechnical Survey data of Erzurum province, which was prepared as the basis for the 1 / 5.000 scale Master Development Plan, which was approved in 2014 and started in 2011.[(20)] Republic of Turkey's current legal regulations and more urbanized areas intersecting (microzonation) in the preparation of

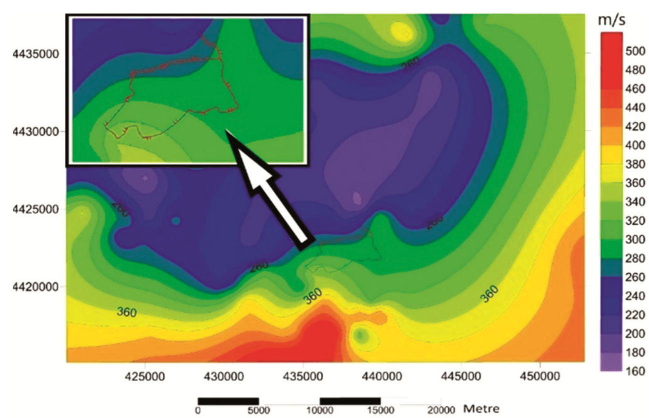

Fig. 5 — LRS route plan and Vs_{30} map of the area

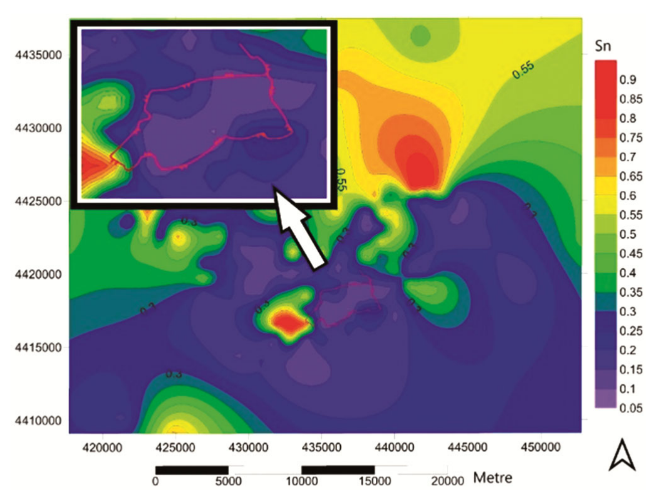

Fig. 6 — LRS route plan and ground master vibration period map for the area

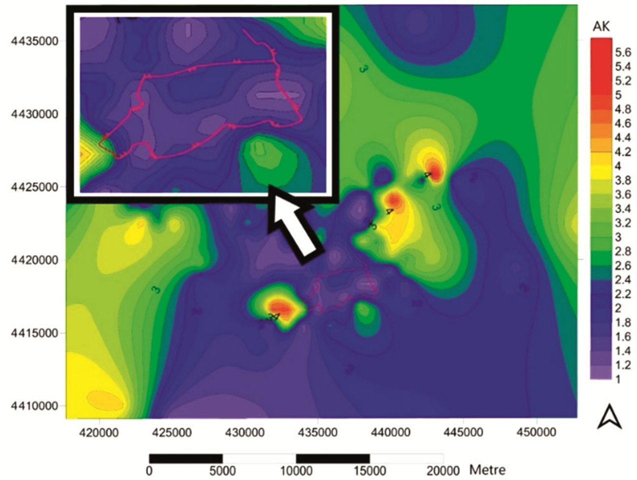

Fig. 7 — LRS route plan and soil amplification value (Av) map of the area

studies that may pose section has not been any study prior to that in 2008. However, while determining the dynamic and mechanical parameters of the ground that forms the basis of our study, the values recorded by drilling, microtremor and seismic recording devices were compared with each other with empirical correlations. The compatibility of the data (as can be observed from the maps) ensures the reliability of the study.

Conclusion and Suggestions

It has been determined that there are some problems such as low ground velocities at points A, B and C on the LRS route, water content, groundwater level. At these points, the ground amplification coefficient and the ground dominant vibration period show high values. Among the application projects to be prepared, first of all, a detailed examination was made in the areas where A, B and C points are located, and the necessity of improvement or revision for these points was revealed. It will be ensured that the ground problems of the LRS route to be revised in this direction are minimized and rail system accidents caused by possible deformations will be prevented.

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