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Seismotectonics of Saydoon Dam Sites in the Izeh Fault Zone, SW of Iran

Arash Barjasteh [1*]

[*1] *Ph.D, Adjunct Lecturer of the Ministry of Energy, KWPA, Ahvaz, Iran*

(barjasteh@hotmail.com)

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ABSTRACT

The effects of Quaternary, Holocene, and historic seismotectonics are of greatest relevance to dam construction. These effects pose the greatest hazards where the magnitudes of earthquakes are large and their hypocenters are shallow. The seismic hazard is the most severe hazard to be considered in the design of large dam projects located in high seismic areas. The earthquake hazard is a multiple hazard, so a thorough investigation is needed for the estimation of the ground motion of the different design earthquakes. This paper gives an overview on the seismotectonic setting of Saydoon dam sites in the context of Izeh fault zone, and the relevant design aspects of the selected dam sites. The main concern of the seismotectonic study is related to the identification and assessment of movements in the dam foundation during strong earthquakes. The presence of active faults and the possibility of movements along discontinuities in the footprint of the dam during strong earthquakes may have severe consequences on the selection of the dam type and the dam site. The Izeh Fault Zone, in which the studied dam sites are located, is a north south-trending structure specified by very intense folding and thrusting as well as medium to high seismicity and has been active during the Mid-Cretaceous and remained active into the Tertiary. Along this transverse fault zone, some evidences of dextral shear deformation structures such as dextral bending of fold axes, strike slip duplexes, and en-echelon folds are developed.

Keywords:

Seismotectonics, Izeh fault zone, Saydoon dam sites, Khuzestan Province.

1. Introduction

Dams are important structures, which have contributed significantly to the economic development of many countries. Most large dam projects are multipurpose projects for energy production, flood control, navigation, water supply and irrigation, recreation, aquaculture etc. As large storage dams may have very large damage potentials, they must also be able to withstand the effects of very strong earthquakes [1]. In many developing countries such as Iran, there is still a large potential for technically and economically feasible dam projects, but these dams may be located in less favorable locations than those already developed. One of the important factors is the high seismic hazard of some of these sites. Therefore, the earthquake load case has become the dominant one for the design of some of the new large dams. The effects of Quaternary, Holocene, and historic seismotectonics are of greatest relevance to dam construction [2]. The Khuzestan province contains the Saydoon dam sites and is formed of the High Zagros and Foothill Folded Series provinces of Nowroozi (1976). The province is a large seismotectonic unit bounded on the northeast by the Main Zagros Thrust, the Kazerun Line on the east, and the Zagros Fold Line on the southwest. On the basis of the occurrence of faulting, the Saydoon dam sites are located within the Simple Folded Zone morphotectonic units as part of the active Zagros Fold-Thrust Belt (Berberian, 1995). The province is considered as one zone from a seismotectonic standpoint as earthquakes appear to be evenly distributed throughout the Khuzestan province (Fig.2). The study area with geographical latitude of 31º, 18´ to 31º, 19´ and longitude of 50º, 10´ to 50º, 15´ is in the north eastern part of the province nearly 30 km southeast of Izeh city (Fig.1). The region is structurally part of Dezful Embayment which is a structural unit of the Zagros Simple Fold Belt. The mentioned unit corresponds to a morphotectonic feature being stepped down due to the Izeh fault (shear) zone. The embayment shows a sharp topographic difference with the Izeh fault zone (IFZ) across the Mountain Front Fault (MFF) and Izeh fault based on elevation difference of Asmari Formation [3-4]. Morphotectonic of the region have also been modified by the Izeh fault system. The present-day configuration of the drainage system in the Izeh Fault Zone, which is characterized by rivers that flow parallel to fold trends, as well as by transverse rivers cutting through folds [5-6]. Large rivers from regions with high topography in the Izeh Zone flow to the Dezful Embayment domain that is characterized by low topographyThe main basement faults in the region are, Mountain Front Fault and Mongasht Fault. However, several fault trends are seen in the region due to compound movement mechanism of the Izeh fault [7].

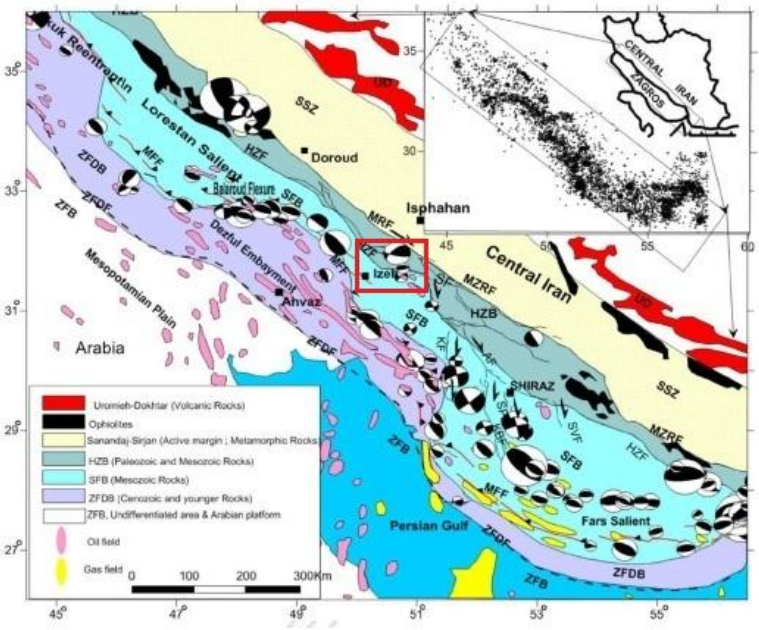

Figure 1. Geographical location of study area after Malekzadeh et al., 2016 [8].

This article assesses seismotectonic features of Saydoon dam sites area related to the structural trends of the basement existing within its vicinity that is the Izeh fault zone. The relation between and hydrogeology and engineering geology of the dam site in the fault zone were investigated [9-11] but their seismotectonic features regarding to the complex nature of the fault zone has not been addressed yet. Three dam alternatives were selected on the existing rivers in this zone which are addressed here as Nayab, Chavil, and Baliab alternatives (Fig.3). The apparent lack of correlation between seismicity and surface geologic structure, due to the presence of ductile layers, made several attempts to assess earthquake-fault hazard study and seismic-risk evaluation in the Zagros very difficult [12].

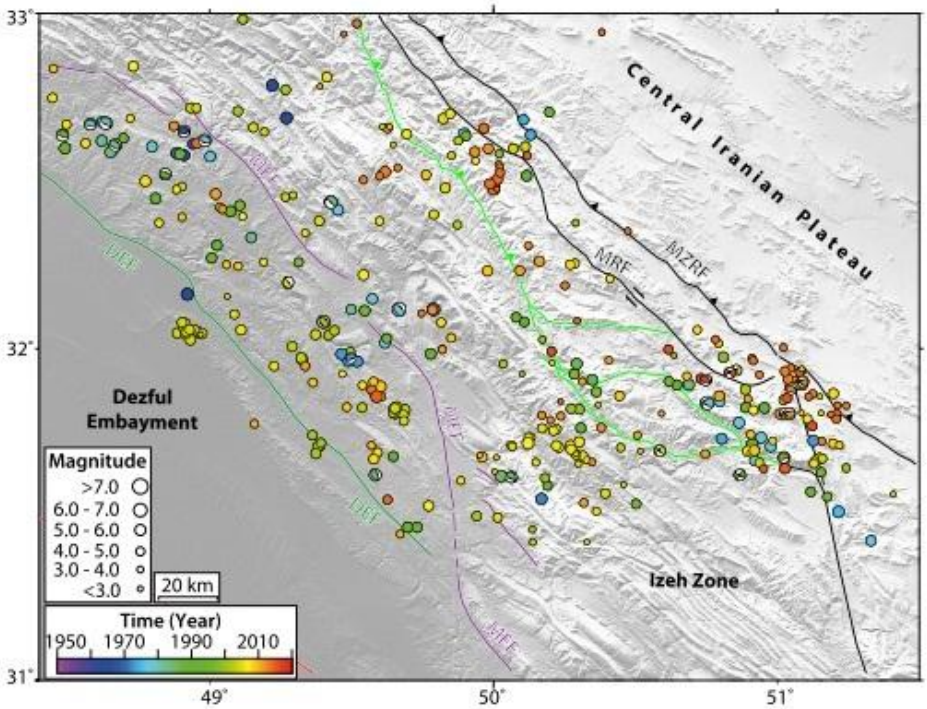

Figure 2. Close-up map of earthquake epicenters in the Izeh zone, showing the intense and scattered seismicity of the region (after Karasozen et al., 2019) [13].

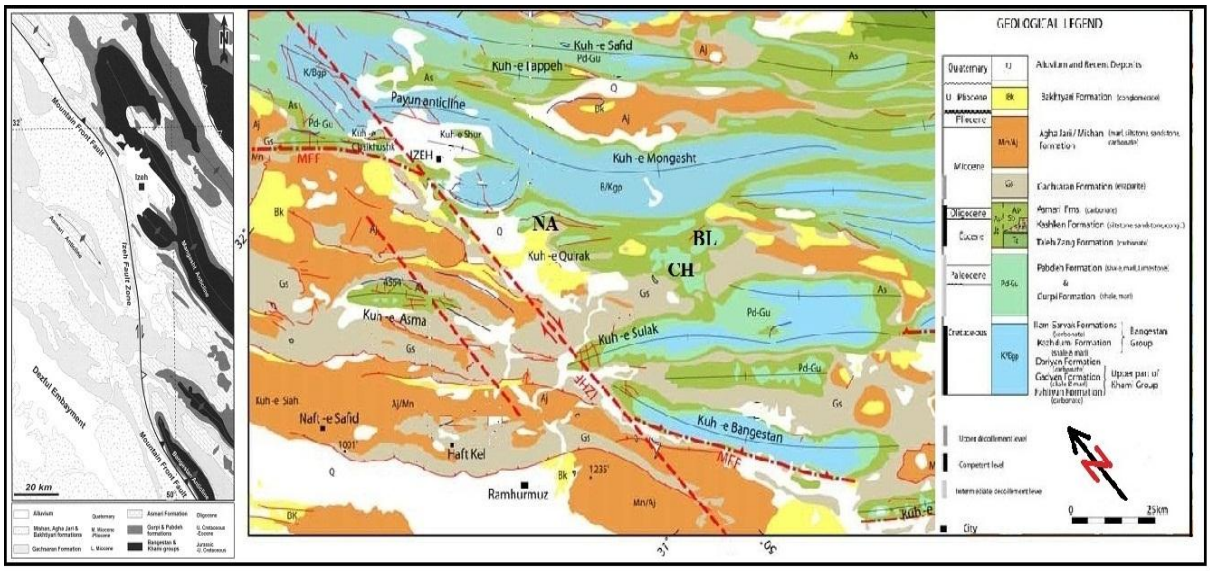

Figure 3. Izeh Fault Zone (left, after Sepehr, 2004) and location of Saydoon dam sites (right, after Ahmadhadi et al., 2008). BL; Baliab, CH; Chavil, and NA; Nayab axes.

2. Geology and Seismotectonics

The Saydoon dam sites are located within the Zagros fold and thrust belt at southeast of Izeh city (southwest of Iran). The dam site is close to two major structures recognized to be currently

active (Figs. 2 and 3) such as: The Main Zagros Reverse Fault, a NE-dipping reverse thrust about 5 km to the Northeast of the dam site. A segment of Mountain Front Fault (N-S trending with right lateral movement) called Izeh Fault (IF). This fault is also considered as a seismogenic source (Fig. 4). The IF is one of the deep-seated faults in the Zagros Fold Belt that its movements has modified sedimentation patterns and deformation styles of geological units in the Central Zagros. Throughout the study area, Asmari formation outcrops (e.g. in Mal Agha, Kuh-e Sefid, and Mongasht anticlines) have been dragged and rotated in a way which is implied on right-lateral displacement of the Izeh fault. Moreover, the movements of the Izeh fault system had been associated with rupturing and or displacement of the Miocene Gachsaran Formation (Flash and Kuh-e Sefid anticlines), too. Morphotectonic features of the region have also been modified by the Izeh fault system. Iran had been affected by this fault system. The Mountain Front Fault (MFF) is the closest seismically active structure to the dam sites. The dam sites are located within valleys that structurally controlled landforms [9-10]. The IF is not a single structure but a zone of individual fault segments, often arranged in an en echelon pattern [14-15].

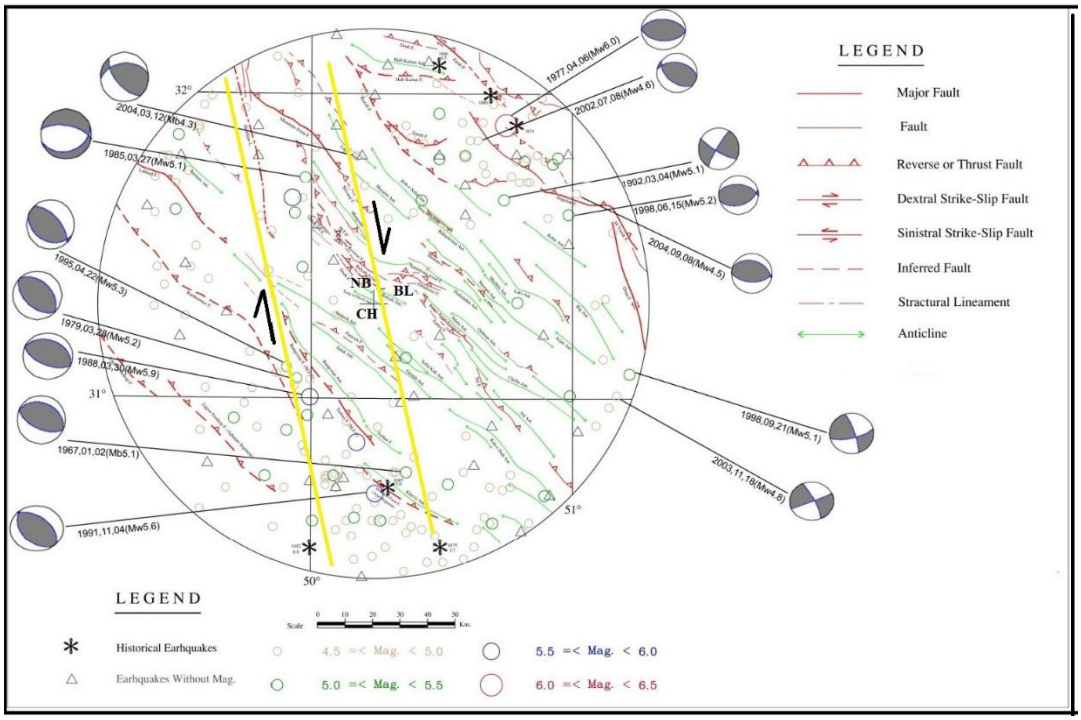

Figure 4. Seismotectonic map of Saydoon dam sites regarding to the Izeh fault zone (yellow lines). BL; Baliab, CH; Chavil, and NA; Nayab axes)

3. Structural Control

Although the study area is located in the Zagros Simply Folded Belt as mentioned above, the geological structure is not so simple and different basement trends caused very clear deflections and displacements in the axes of the existing anticlines together with a few number of fracture systems and faults (Fig.3). This case is more observed in mountain anticline and synclines. The complexity of structures is related to the tectonic position of the selected sites. In the belt, the approximate locations of the basement faults have been identified using different methods

(Berberian, 1995). They include some trends such as the Mountain Front fault (MFF), the Dezful Embayment fault (DEF), and the Zagros Foredeep Fault (ZFF) having an average dip of 60؛ NE, and some others such as the Izeh Fault (IZF), the Kharg-Mish Fault (KMF) and the Kazerun Fault (KZ) with nearly N-S trend showing right-lateral strike-slip motion. Of the latter group, Izeh fault plays a key role in the study area due to its short distance. Identifying the existing basement trends in the vicinity of Saydoon dam site together with fracture survey (Fig.5) in the study area and on the proposed axses shows that not only the valley but also surrounding anticlines and synclines are highly affected by the local structure which in turn extensively influenced by the Izeh fault zone. The average dip of bedding varies between 10 and 15 degrees but its trends changes extensively doe to the location of data gathering that is affected by existing faults. The location of faults intersections is very good coincident with the places where hydrogeological or engineering geologic parameters and conditions change. The main trends of the defined basement structures and fractures indicate a general N-S prevailing trend for regional fracture pattern that is comparable to the Izeh fault trend.

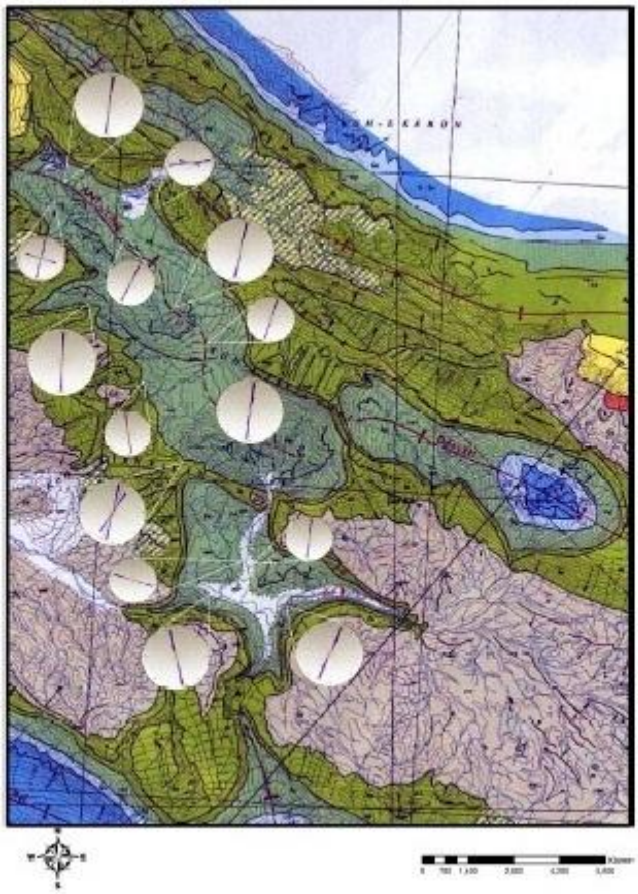

Figure 5. Rose diagram of main fractures in the studied area (modified after Hamoudi 2011) [16].

4. Local Faults on Dam Foundations

The main faults in the region are Mongasht and Kuh-e Sefid faults with an average length of 64 and 34 km, respectively. Their sense of movement is known as reverse mechanism. A number of small faults there are on dam sites (Fig.6). Some of these faults show left-laeteral displacement but most of the are right lateral faults. The structural analysis of the fracture trends data indicated several fracture systems with varied lengths and orientations. Generally, throughout the area there are two trends for the main fracture sets (N-S and NE-SW trending) suggested that these sets were probably related to reactivation of the Izeh fault during the Zagros orogeny [14-15].

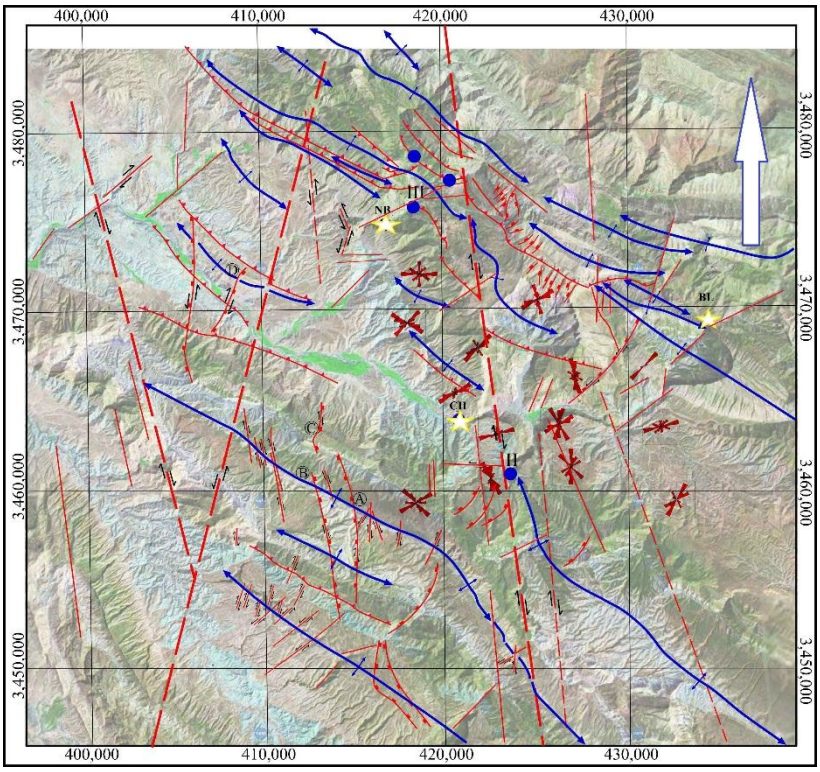

Figure 6. Main fault and structural trends of Saydoon dam sites region.

5. Optimum Dam Type

Regarding to the uncertainties with respect to possible movements in the dam site region, an embankment dam would be the preferred solution. Conceptual studies have shown that embankment dams are feasible for this site. The main item needed as a basis for the selection of the dam type is the seismotectonic design criteria. If displacements along discontinuities in the vicinity of the dam sites are small (in the range of few centimetres) then, any type of embankment dam is safe. The average estimated values for DBE and MCE values are 0.19g and 0.55g, respectively. The calculated b-values for the mentioned sites are 2.43, 2.53 and 2.46, respectively indicating high seismicity of the zone (Fig.7). Most of the events had focal depths between 30and 35km. Analysis of structural elements in the region indicated a mean direction of N44ºE for maximum compressional stress. (Fig.5). According to ICOLD Bulletins for sites with PGA greater than 0.25g and active fault closer than 10 km from site, separate consideration of MDE (Maximum Design Earthquake) OBE (Operating Basis Earthquake) and RIE (Reservoir Induced Earthquake)

are required. At sites where movements along discontinuities (faults, joints, bedding planes etc.) in the footprint of the dam are possible during strong earthquakes a flexible embankment dam, such as a well-designed earth core rockfill dam, is the safest option [1,17]. However, the proximity of important faults may have direct implications on the available dam options, a subject that was ignored almost up to now.

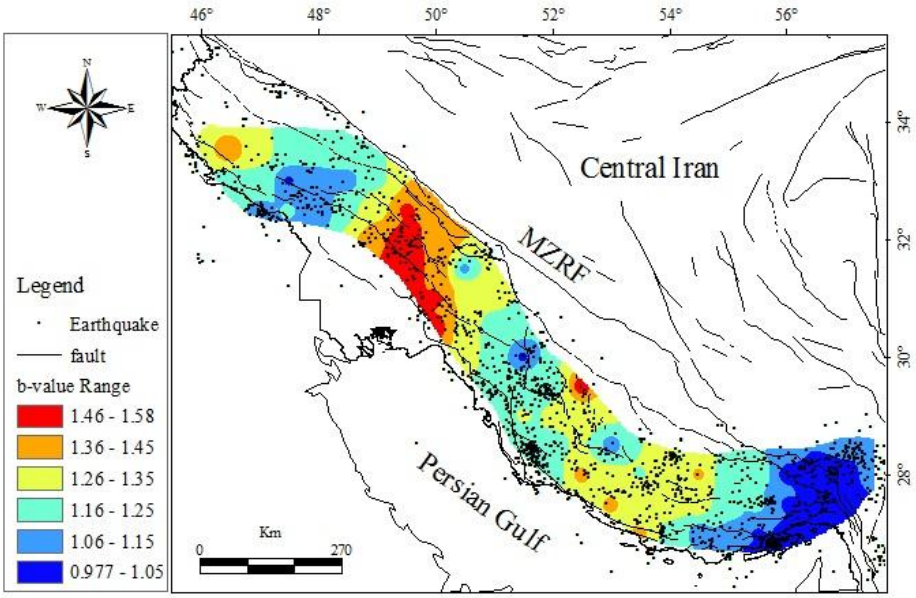

Figure 7. b-values Main tectonic trends of Saydoon dam sites (BL; Baliab, CH; Chavil, and NA; Nayab axes).

6. Conclusion

Considering the above discussed items, all studies, report and technical discussions, following points are deduced:

1. Various fault and fracture trends in the region indicate that the Izeh fault zone is complex structure with different displacements causing a complicated design and scenario along fault and/or discontinuities in the dam sites region.

2. the Izeh fault zone has been marked by right-lateral dragging and rotation of fold axes, and rupturing and or displacement of sedimentary strata.

3. The calculated b-values for the mentioned sites are 2.43, 2.53 and 2.46, respectively indicating high seismicity of the zone.

4. Most suitable solution against displacement while occurrence of severe earthquake is to use flexible and clay material including the building of clay core and filter.

7. References

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