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Investigation of Seismic Behaviour of a Construction of a Conveyor Line in a Coal Power Plant

Erinç ULUDAMAR[*1] ORCID *0000-0001-5247-5057*
Sinan EGÜZ[2] ORCID *0009-0009-0500-9534*
Kerimcan ÇELEBİ[3] ORCID *0000-0001-6294-0872*
Sedat KARAAHMETLİ[4] ORCID *0000-0002-5906-8216*

[1]Adana Alparslan Türkeş Science and Technology University, Faculty of Engineering, Department of Mechanical Engineering, Adana, Türkiye
[2]İSKEN - Sugözü Power Plant, Adana, Türkiye
[3]Cukurova University, Faculty of Ceyhan Engineering, Department of Mechanical Engineering, Adana, Türkiye
[4]Adana Alparslan Türkeş Science and Technology University, Faculty of Engineering, Department of Civil Engineering, Adana, Türkiye

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Abstract

The conveyor line that carries raw materials from storage area to inside of a facility is the main vessel of a coal power plant. Therefore, this critical line should be designed by considering the many loads likely to be exposed in the field in order for the plant to operate uninterruptedly. In this study, seismic behaviour of a construction of a conveyor line was investigated by using Finite Element Analysis. The structure of coal carrier conveyor line of a coal power plant, operating in Adana, Türkiye was considered as a case study. In the study, the parts of the conveyor line were modelled as 1-D. The modified acceleration history of Golcuk-1999 earthquake was applied on the structure on lateral direction. The results showed that the maximum stress is slightly higher than the elastic limit of the steel and less than the ultimate strength. Although the construction of the conveyor line withstands the applied loads, modification should be carried out to prevent the damage on the construction.

Keywords: Seismic behaviour, Earthquake, Finite element analysis, Power plant, Conveyor line

Bir Kömür Santrali Konveyör Hattının Sismik Davranışının İncelenmesi

Öz

Hammaddeleri depolama alanından tesis içine taşıyan konveyör hattı, bir kömür santralinin ana damarıdır. Bu nedenle kritik öneme sahip bu hat, santralin kesintisiz çalışabilmesi için sahada maruz kalması

[*]Sorumlu yazar (Corresponding Author): Erinç ULUDAMAR, *euludamar@atu.edu.tr*

muhtemel birçok yük dikkate alınarak tasarlanmalıdır. Bu çalışmada, bir konveyör hattı konstrüksiyonunun sismik davranışı Sonlu Eleman Analizi kullanılarak incelenmiştir. Türkiye, Adana'da faaliyet gösteren bir kömürlü termik santralinin kömür taşıyıcı konveyör hattının yapısı örnek olay olarak ele alınmıştır. Çalışmada, konveyör hattının parçaları 1-B olarak modellenmiştir. Gölcük-1999 depreminin ivme geçmişi değiştirilerek yapıya yanal yönden uygulanmıştır. Sonuçlara göre maksimum gerilmenin çeliğin elastik sınırından biraz daha yüksek ve nihai dayanımdan daha düşük olduğunu göstermiştir. Konveyör hattının konstrüksiyonu uygulanan yüklere dayanmasına rağmen konstrüksiyona zarar vermemek için modifikasyon yapılmalıdır.

Anahtar Kelimeler: Sismik davranış, Deprem, Sonlu elemanlar analizi, Enerji santrali, Konveyör hattı

1. INTRODUCTION

Every year, approximately 500.000 detectable earthquakes, which 100.000 of them can be felt by human, is located around the globe [1]. Large-scale natural disasters such as earthquakes are frequently occurred in many regions of Turkey as well. Post-earthquake damages of power plants have posed an increasing concern by engineers since the power supply to damaged settlement by earthquakes is crucial for rescue works and aids.

The main active tectonic feature of Adana Basin is the left lateral of Toprakkale and Yumurtalık faults [2]. The coal power plant is located approximately 10 km from the centre of Yumurtalık-Sugözü town of Adana Province.

Earthquakes are a frequent natural disaster that poses a significant threat to infrastructure, including power plants. Therefore, in the present study, the seismic behaviour of a steel constructed coal conveyor line of a coal power plant was investigated as a case study.

In previous studies, Weng et. al., studied on system identification method for material constitutive nonlinear structures subject to unknown input earthquake excitation [3]. In the study, they modelled the nonlinear fiber beam-column model, and the input earthquake is parametrized by Chebyshev orthogonal polynomials and they optimized the process. As a result, the proposed model recognized the earthquake input and sensitivity analysis to accelerate optimization. Mazzieri et. al., performed the case study of the Tahtalı dam in İzmir earthquake 2020 [4]. They considered an abstract mathematical, three dimensional, elasto-acoustic coupled wave-propagation model. Ansys software program is commonly used by researchers for seismic analysis. Yan et. al., performed the program to investigate the structural dynamics of 10 MW offshore wind turbines with monopile, tripod and jacket substructures [5]. They resulted that the tower top displacement is the most with monopile, followed with jacket and tripod, respectively under 7 measured on a Richter scale earthquake and compared to monopile, the maximum stresses of the jacket and tripod are 5.7 and 2.3 times, respectively whereas the average stress is 0.74 and 0.56 times, respectively. Xunqiang et. al., developed a method and implemented in the ANSYS Release 11.0 software program [6]. They developed the method for nonlinear seismic analysis of large 3-D structures which are rises on unbounded visco-elastic soil. For a broad frequency range, better convergence during the extraction process and convenient modelling of bounded soil without selecting a particular artificial damping was assured with the formulations. Das et. al., investigated damping effectiveness of installed deep liquid tanks on the roof of asymmetric high-rise buildings on controlling the seismic response [7]. In the study they coupled Fluent and Mechanical solvers in ANSYS software program. According to their findings, response is 79.37% reduced with traditional tuned liquid dampers, whereas the tuned mass damper 100% reduction. They recommended that eccentrically placed deep liquid tanks may provide better control in L-shaped high-rise buildings. Yang et. al., 2023 studied on the seismic performance of height-to-diameter ratios, storage categories, and site soil categories of column-bearing concrete vertical silos [8]. They modelled the silos using ANSYS Workbench and found out that the seismic performance of the building increased with the fibers in concrete.

Morelli et. al., investigated the impact of retrofitting an existing industrial steel building using the steel self-centering device (SSCD) on the global seismic response. A parametric analysis is conducted to emphasize the effect of various parameters defining the device's hysteresis cycle on the overall behaviour of the structure. The structure's performance is primarily assessed based on three parameters: maximum displacements, residual displacements, and the seismic energy absorbed by the structure. The results obtained underscore the effectiveness of SSCDs in enhancing the seismic performance of the building and increasing its resilience by reducing residual displacements [9].

Li et. al., produced three 1:2 scale steel frame samples and tested them on a shaking table at five different ground acceleration levels. Then, the damage modes, dynamic responses, displacement responses, strain responses and acceleration responses of various steel structures with different connection types were analysed. Experimental results were verified using the finite element method. This study aims to provide a guide on the seismic design of steel frames with ductile connections [10].

Yang et. al., emphasized in previous studies that seismic design methods of steel silos are not included in detail in current regulations. Therefore, they aimed to develop a new understanding of the interaction mechanism and response of grain cast steel silos under earthquake loads [11].

The purpose of this study is to investigate the seismic behaviour of a coal conveyor system with a steel structure in a coal power plant and to understand how stress levels on this system are related to the supporting height. The findings highlight the importance of evaluating the seismic performance of the conveyor system by demonstrating that high stress levels lead to the bending of the bridge profiles. Furthermore, the study emphasizes the need to make infrastructure of this kind more resilient to seismic risks and underscores the importance of taking appropriate measures to mitigate the potential effects of earthquakes. This study can be considered as an important step in understanding and improving the seismic behaviour of critical infrastructure.

2. MATERIAL AND METHOD

Each of the steel profile of conveyor line was prepared as 1-D and analysed in ANSYS Workbench software program. In Figure 1, the modelled conveyor line was shown in the field. In the model, it was considered that there is no pre-deformation and corroded material in the structure of the line. The conveyor line on the field was shown in Figure 1. The investigated part of the conveyor line was named as shown in Figure 2.

Figure 1. The conveyor line

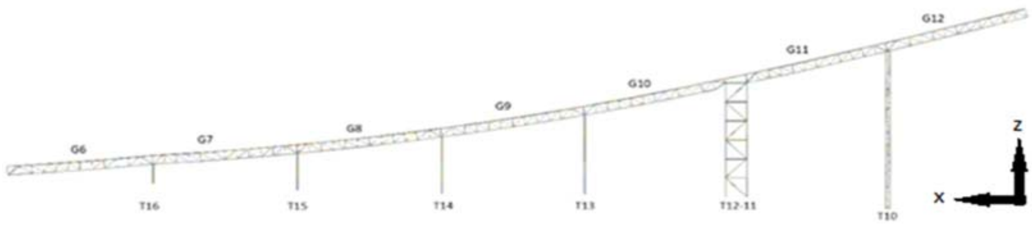

Figure 2. Model of the conveyor line

The material of the conveyor line is SABS 1431 300WA quality steel. The chemical composition and mechanical properties of the steel were presented in Tables 1 and 2, respectively.

Table 1. Chemical composition of SABS 1431 300WA steel as percent

C	**Mn**	**Si**	**P**	**S**	**Nb**	**V**	**Nb**	**Al**	**Cu**	**Ni**	**Cr**	**Mo**
0.2	1.6	0.5	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.3	0.1

Table 2. Mechanical properties of the steel

Density		7850	kg/m^3
Young's modulus		200	GPa
Poisson's ratio		0.3	
Minimum yield strength	3<t<16	300	MPa
	16<t<40	300	MPa
	40<t<63	290	MPa
	63<t<80	280	MPa
Elongation	50 mm	24	%
	200 mm	20	%
	5.65 So	22	%
Tensile strength		450	MPa

In the meshing operation, each of the steel profile was divided into 20 elements. Thus 67264 nodes and 34321 elements were obtained on the model.

- The boundary conditions and assumption of the modal is as follows (Figure 3);
- All degrees of freedom of the ground contact points of carriers T10, T11, T12, T13, T14, T15, T16 were fixed.
- Displacement at x-, y-, and z- directions of the idle points of G6 and G12 conveyors were assumed as 0.
- The own weight of the line (67,357 kg)
- 29,000 kg distributed weight to simulates the weight of parts (fasteners, tape, rollers, etc.) which were not included in the model,
- 10,500 kg distributed weight to simulate coal weight.
- Earthquake acceleration from lateral direction.

Standard earth gravity and acceleration data was applied on the model. The acceleration data includes the most severe 6.41 seconds long of Gölcük-1999 (Mw=7.4) earthquake with 0.01 second intervals. The graph of time history data of applied acceleration was illustrated in Figure 4.

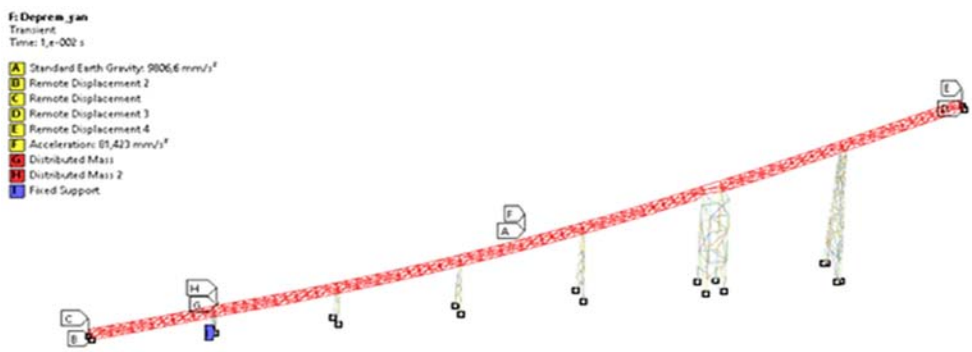

Figure 3. Boundary conditions of the model

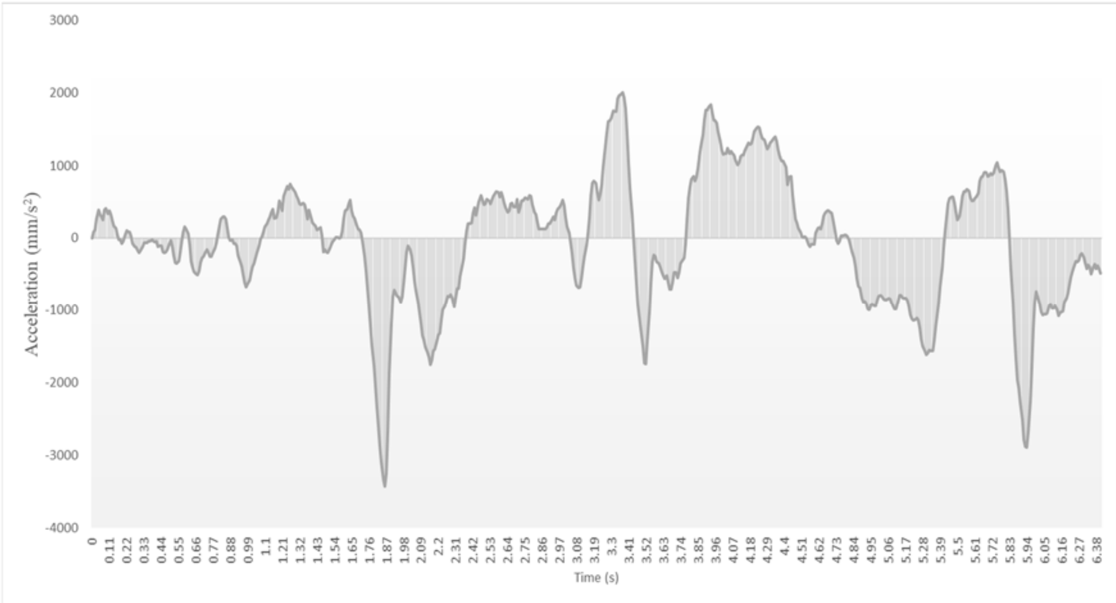

Figure 4. Time history of applied acceleration

3. RESULTS AND DISCUSSIONS

According to results of numerical method, stress of all carriers is at acceptable levels. The analyses result showed that the highest stress increased primarily with the height of the carriers. Moreover, the stresses that occurred in gantries also increased with the height of the carriers. This increment may relate with the high deformation of carriers forces to elongate and buckling of gantries' profiles.

Unfavourably, the stress level increases beyond the yield strength of the material in G9 and G11. The highest stress was occurred in G11 as 425.9 MPa. In G9 the highest stress was 347.8 MPa. For the other gantries, the highest stress is lower than the yield strength of the material however, modification should be performed on the gantries considering the safety factor. Although it was observed that the stresses of G12 were lower than G11, it was evaluated that the main reason for this may be due to the boundary condition taken as 0 displacement at x-, y-, and z- directions, in the connection point of G12 to the building which is not included in the model. It has been evaluated that the deformation and stresses occurring in G12 may vary according to the building oscillation, and G12 should also be considered as risky.

The highest stress and deformation results of each part were shown in Table 3. Moreover, in Figures 5 and 6 the stress history of G9 and G11 were presented, respectively. The stress distribution at 3.64 seconds, when the highest stress was observed, was shown in Figure 7.

Table 3. The highest stress and deformation results

		Max.		Min.	
T16	*Direct Stress*	22.5	MPa	-52.2	MPa
	Minimum Combined Stress	21.8	MPa	-60.8	MPa
	Maximum Combined Stress	28.8	MPa	-50.7	MPa
	Total Deformation	1.8376	mm	-	
T15	*Direct Stress*	62.8	MPa	-69.9	MPa
	Minimum Combined Stress	62.5	MPa	-85.8	MPa

	Maximum Combined Stress	72.1	MPa	-69.7	MPa
	Total Deformation	6.0295	mm	-	
T14	*Direct Stress*	113.8	MPa	-115.7	MPa
	Minimum Combined Stress	113.5	MPa	-123.7	MPa
	Maximum Combined Stress	120.3	MPa	-115.4	MPa
	Total Deformation	18.629	mm	-	
T13	*Direct Stress*	83.4	MPa	-85.0	MPa
	Minimum Combined Stress	83.1	MPa	-91.9	MPa
	Maximum Combined Stress	88.7	MPa	-84.9	MPa
	Total Deformation	17.758	mm	-	
T12-11	*Direct Stress*	110.2	MPa	-126.3	MPa
	Minimum Combined Stress	108.8	MPa	-137.9	MPa
	Maximum Combined Stress	128.7	MPa	-125.5	MPa
	Total Deformation	51.398	mm	-	
T10	*Direct Stress*	104.4	MPa	-98.0	MPa
	Minimum Combined Stress	103.1	MPa	-109.3	MPa
	Maximum Combined Stress	120.9	MPa	-97.6	MPa
	Total Deformation	51.398	mm	-	
G6	*Direct Stress*	86.0	MPa	-52.5	MPa
	Minimum Combined Stress	84.0	MPa	-217.2	MPa
	Maximum Combined Stress	196.5	MPa	-51.09	MPa
	Total Deformation	20.243	mm	-	
G7	*Direct Stress*	87.4	MPa	-48.3	MPa
	Minimum Combined Stress	84.7	MPa	-125.4	MPa
	Maximum Combined Stress	123.2	MPa	-43.4	MPa
	Total Deformation	20.7	mm	-	
G8	*Direct Stress*	86.7	MPa	-57.4	MPa
	Minimum Combined Stress	84.2	MPa	-278.5	MPa
	Maximum Combined Stress	232.2	MPa	-56.0	MPa
	Total Deformation	29.518	mm	-	
G9	*Direct Stress*	87.7	MPa	-74.4	MPa
	Minimum Combined Stress	85.1	MPa	-347.8	MPa
	Maximum Combined Stress	292.24	MPa	-73.1	MPa
	Total Deformation	39.27	mm	-	
G10	*Direct Stress*	91.2	MPa	-76.4	MPa
	Minimum Combined Stress	88.2	MPa	-235.8	MPa
	Maximum Combined Stress	226.1	MPa	-74.6	MPa
	Total Deformation	52.301	mm	-	
G11	*Direct Stress*	103.9	MPa	-87.4	MPa
	Minimum Combined Stress	103.0	MPa	-421.9	MPa
	Maximum Combined Stress	425.9	MPa	-81.0	MPa
	Total Deformation	76.776	mm	-	
G12	*Direct Stress*	123.3	MPa	-141.5	MPa
	Minimum Combined Stress	119.2	MPa	-263.7	MPa
	Maximum Combined Stress	248.3	MPa	-139.4	MPa
	Total Deformation	55.898	mm	-	

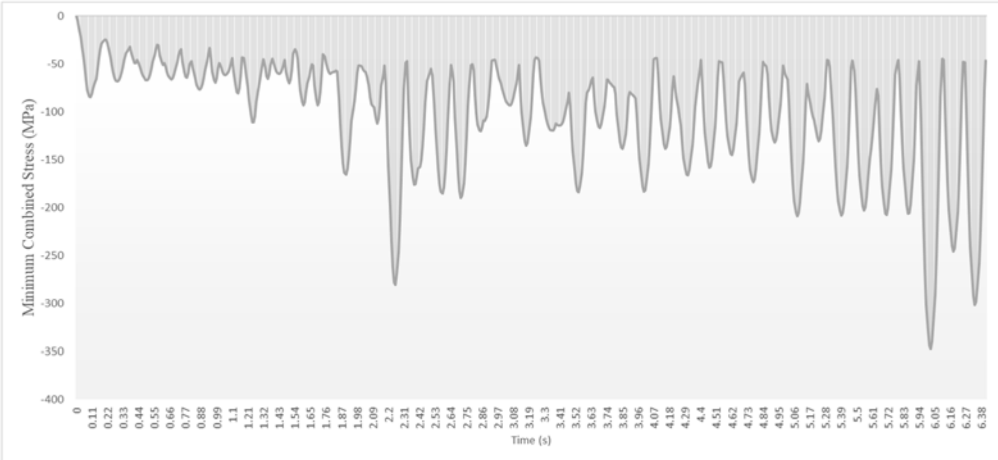

Figure 5. Stress history of G9

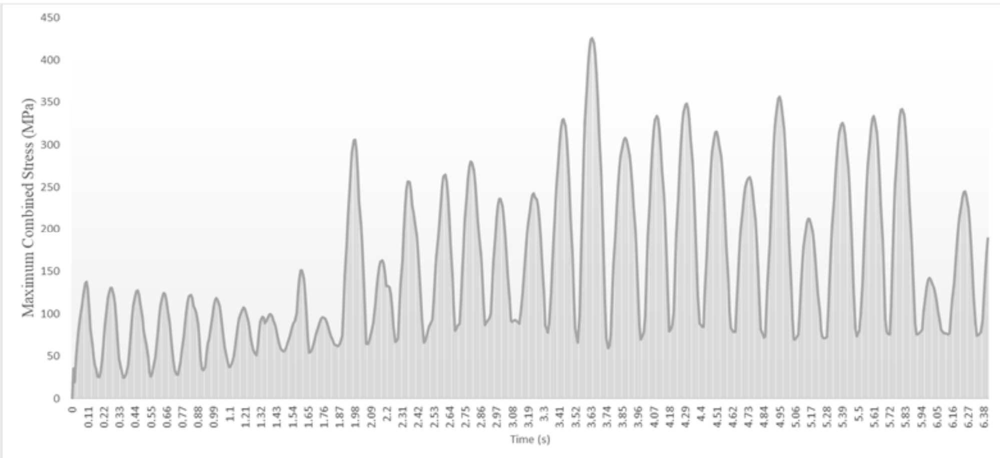

Figure 6. Stress history of G11

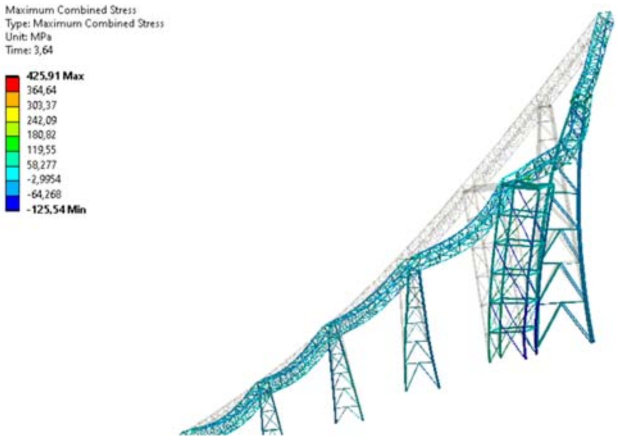

Figure 7. Stress distribution

4. CONCLUSION

In this study, seismic behaviour of a steel constructed coal conveyor line of a coal power plant was investigated. The results showed that the stress levels in all carriers were increased primarily with the height of the carriers, leading to buckling of the gantries' profiles.

The stress level increased beyond the yield strength of the material in G9 and G11. Additionally, stress level of G12 should be considered as high as the connected building model did not include in the analysis. In other gantries, modifications should also be considered to increase the safety factor.

The findings of this study demonstrate the need for improvement of the conveyor line should be evaluated. It is crucial to ensure that infrastructure is designed and constructed to withstand the forces generated by seismic events and to identify potential risks and take appropriate measures to mitigate them. In conclusion, this study highlights the importance of understanding the seismic behaviour of critical infrastructure and minimize the damage and impact of earthquakes.

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