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Investigation of the Effect of changing the degree of freedom at the connection point of support to the foundation on the seismic behavior of the SUPPORTING of the gas pressure reducing station

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Abstract

This study aimed to study the seismic behavior of the SUPPORTING of the gas pressure reducing station due to the change in the degree of freedom at the SUPPORT to the foundation connection point. In this research, the effective parameters on stress analysis of supports in the gas station have been studied and numerically analyzed as a case study using the high-pressure station type map implemented by the National Iranian Gas Company to identify the factors affecting the design and strengthening of the gas station PIPING system. The results showed that the change in the degree of freedom at the SUPPORT to the foundation connection point on the seismic behavior of the SUPPORTING (as metal support and concrete support) of the gas pressure reducing station had a notable impact on the seismic bearing capacity of the PIPING system. The effect of changing the degree of freedom at the connection point of SUPPORT to the foundation on the seismic behavior of SUPPORTING gas pressure reducing station by changing the type of connection of pipes to the ground with metal support and concrete support showed the amount of final bearing capacity compared to the use of metal bases was 16.89% more effective.

Keywords: Numerical analysis of support, Support stress, Gas station

Introduction:

Because Iran is a seismic country, it is necessary to consider the lateral force caused by earthquakes in the design of various construction and industrial structures. Natural gas pressure reduction stations are one of the most vital facilities in supplying gas to cities, villages, and industries. In the design and construction of most advanced facilities, such as petrochemicals and refineries, special attention has been paid to evaluating the seismic vulnerability of the supports used in the equipment and piping system. However, this critical issue is nearly ignored in the case of equipment supports and piping systems for gas pressure reduction stations. Considering that gas pressure reduction stations are vulnerable to earthquake dynamic forces, which leads to a loss of national capital, the stability and resilience of these structures are crucial. In this respect, understanding the seismic behavior and function of pipes, especially how to connect and restrain pipes, as one of the most critical arteries, seems necessary.

Qashqaei and Afshar (1398) have investigated the seismic performance of the pipeline support system in gas stations equipped with separators under earthquakes far from faults. This case study has investigated the gas station northwest of Qazvin, selected part of the transmission system equipment, including tank and pipe, and modeled it in Sap software. A separator under the heat source has been employed for reinforcement. Analyzes include displacement, acceleration, and shearing in the tank and pipe components. Examination of the results showed that compared to the main structure, acceleration and displacement in the sub-source nodes in the reinforced structure have increased, and the base shear has reduced [2]. Fanaei et al. (2008) dynamically simulated the gas transmission pipeline from the Khangiran refinery to Ramsar booster station. In this simulation, HYSYS software is employed, but its Gas Pipe set is used, which is used in an unstable mode. Pipeline

temperature changes and a daily gas consumption pattern in the form of a hypothetical sine function and taking into account the parameters of the compressor, powerhead, and efficiency based on the flow rate and rotation speed of the compressor blades are the features of their research [4].

Niknam (2005), in an article named "Simulation and optimization of gas transmission pipelines to solve the problem of gas pressure drop," has addressed solutions such as using a parallel (auxiliary) pipe next to the main pipeline using HYSYS software (Pipe Segment, for the static solution of single-phase gas). He has examined the length and diameter of the auxiliary pipeline separately for the different situations between each pressure boosting station. Studying the possibility of abrasion problem in the auxiliary line and then choosing the best diameter and length of the auxiliary line in terms of the Final price objective function of the auxiliary pipeline cost is one of the outcomes of this research [6]. Izumi Nakamura et al. (2013) tested the PIPING system with two tank and valve fittings with flange connections and supports in various small-scale models mounted on a vibrating table with variable acceleration intensity. The results of this test revealed that the PIPING system was more damaged at the pipe support points. It was also found that the SUPPORTING and PIPING system utilized has a unique seismic capacity due to design constraints [8].

Halabian et al. (2008) studied the impact of nonlinear properties of soil, matter, and geometric nonlinearity on the interaction of soil and pipes under the influence of permanent deformations of the earth on the resistance of buried pipes to earthquakes. The outcomes of the numerical analysis prove that with increasing fault displacement, the maximum strain increases, and local buckling may happen. Also, for larger transition angles, the strain increase is more noticeable [10]. Liu et al. (2010) studied and analyzed the failure of buried X65 gas pipelines under the force of displacement using the finite element method. In this research, the pipe was subjected to a parabolic displacement along its axis. The outcomes showed that pipelines show higher load-bearing capacity in sandy soils than in cohesive soils [12].

The numerical modeling of the dynamic behavior of high-pressure natural gas flow in pipelines was done by Gatto and Henriques (2005) by solving the survival equations for a one-dimensional compressible flow using the Galerkin method of discontinuous Rang-Kata and estimating the quadratic in space and time. The phenomenon of pressure fluctuations in gas pipelines has been studied due to the density wave created by the rapid shut-off valve closing downstream of the pipeline. The impact of the reflection of partial pressure waves in pipelines with different cross-sectional areas was also analyzed [14].

If an earthquake happens and the pressure reduction station is out of service or is seriously damaged because of failure to identify critical points and inadequate support and the areas to which the station is responsible for supplying gas are not harmed and continue to require gas, particularly in industries that are chief consumers of natural gas, in addition to creating a social crisis, the National Iranian Gas Company will lose its source of income for a while. Therefore, this study seeks to examine the impact of changing the degree of freedom at the connection point of support to the foundation on the seismic behavior of the SUPPORTING of the gas pressure reduction station.

Materials and methods

In this research, ANSYS software was employed to investigate the influence of changing the degree of freedom at the point of connection of the support to the foundation. Design and construction of gas stations in the IGS standard of the National Iranian Gas Company follow the IGEM / TD / 13 Edition 2 standard and the ASME B31.8-2016 standard. Seismic load is applied according to ASCE 7-2016 standard. The steel worked in the construction of supports is ST37 and is chosen according to AISC77.BIN standard.

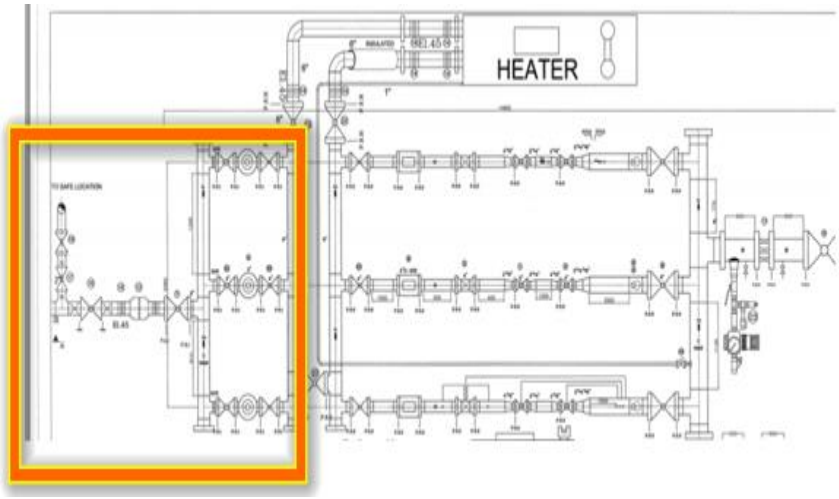


Figure 1. High-pressure station type plan implemented by National Iranian Gas Company (case study)

Figure 2. Metal support of the station understudy

Figure 3. Concrete support of the station understudy

Seismic behavior of SUPPORTING gas pressure reducing station by changing the degree of freedom at the point of connection of SUPPORT to the station foundation as a result of changing the type of connection from metal foundations (described in the previous section) to concrete foundations with dimensions of 20 × 40 cm that is

the boundary conditions with varying degrees of freedom have been investigated according to Figure (4) (the metal type acts as a joint and the concrete foundations are completely rigid).

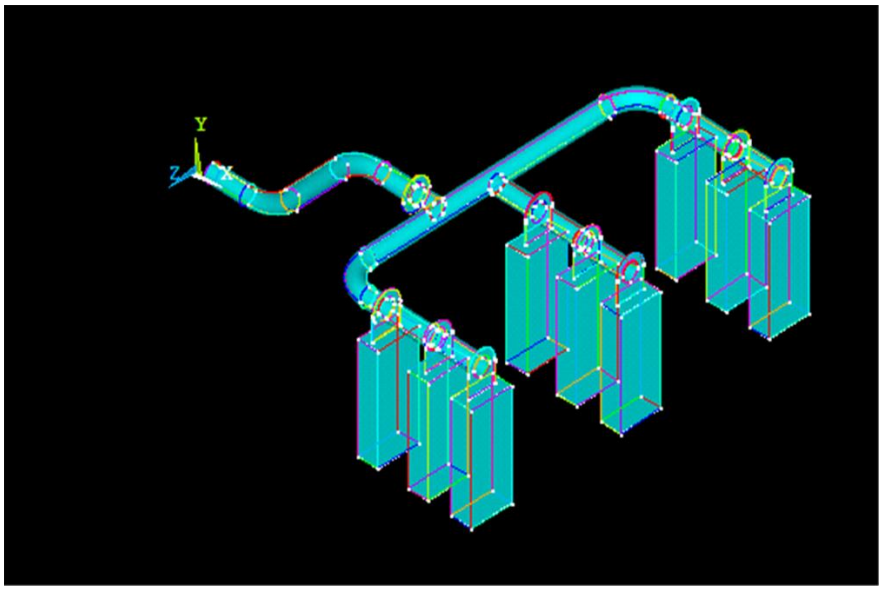


Figure 4. Modeling of the concrete support of the case study station in the Ansys program

In this study, the specifications of the studied materials are presented in Table (1-3).

Table 1. Material specifications

ST37 steel materials	
M Unit volume mass (in MKS system)	800.2Kg/m^3
W Unit weight volume (in MKS system)	7850kg/m3
E_S modulus of elasticity	2×106kg/cm210^6 Kg/cm^2
F_y Steel yield stress	2400Kg/cm^2
F_u final stress of steel	3700Kg/cm^2
Concrete materials category C30	
M mass unit volume	255 Kg/m^3
W unit weight volume	2500 Kg/m^3
E_S modulus of elasticity	2 ×10^5 Kg/cm^2
Poisson's ratio	0.2

Meshing based on mesh size is calibrated by changing the mesh size according to the laboratory results of the model; The model mesh is presented in Figure (5), Figure (6), and Figure (7). As displayed in the figures, the 45-

degree pipe extrudes from the ground. The buried part is entirely rigid, and a cyclic force is applied to the end of the pipe, according to ATC24. It should also be noted that according to the ASCE 2016-2017 standard, the amount of seismic load required by design is equal to 3600 kg. After drawing the model, this value is also controlled so that the model has sufficient resistance.

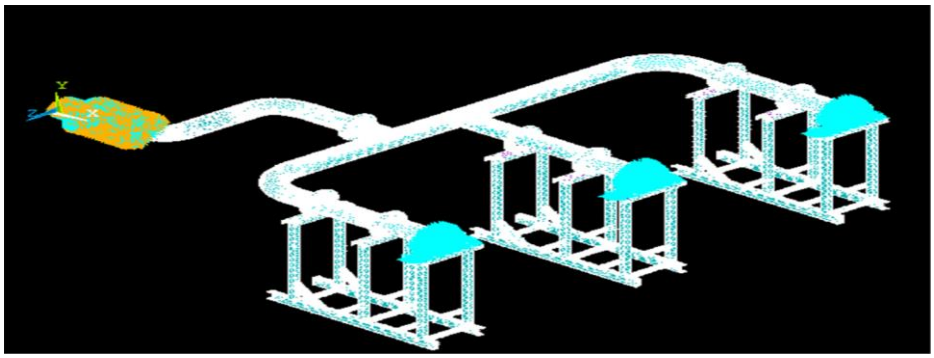


Figure 5. Meshing: Metal support model with intermediate relations of the studied station in Ansys program

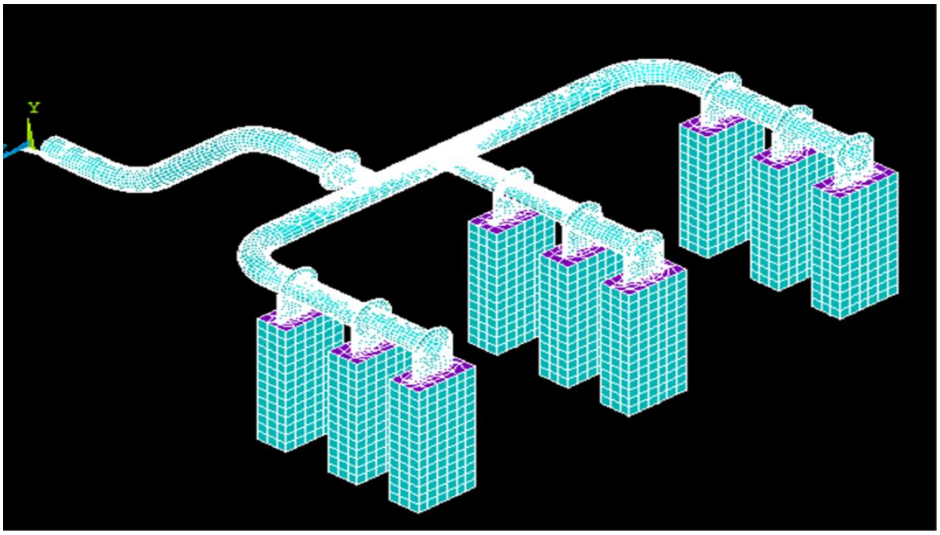


Figure 6. Meshing: Concrete support model with intermediate relations of the studied station in Ansys program

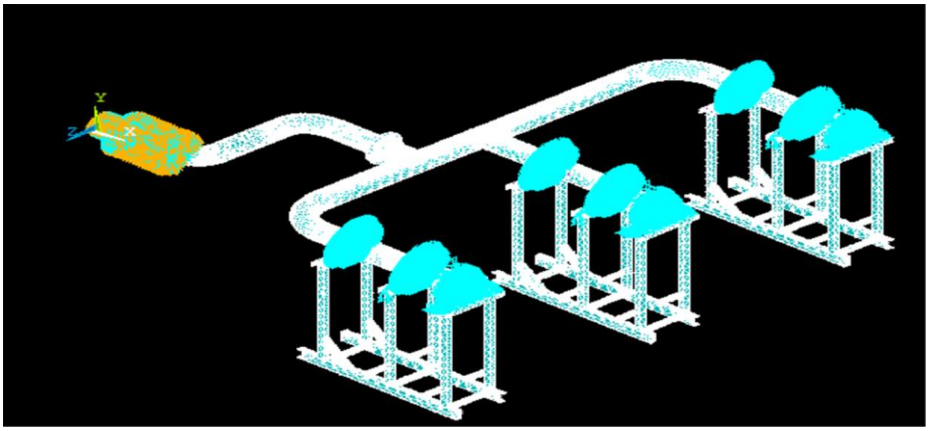


Figure 7. Final meshing of the model

Validation

First, the validation results are reviewed. In order to compare the results of modeling with Izim's (2015) research, modeling has been performed for validation, and then analysis has been performed. The software results are shown in Figure (8).

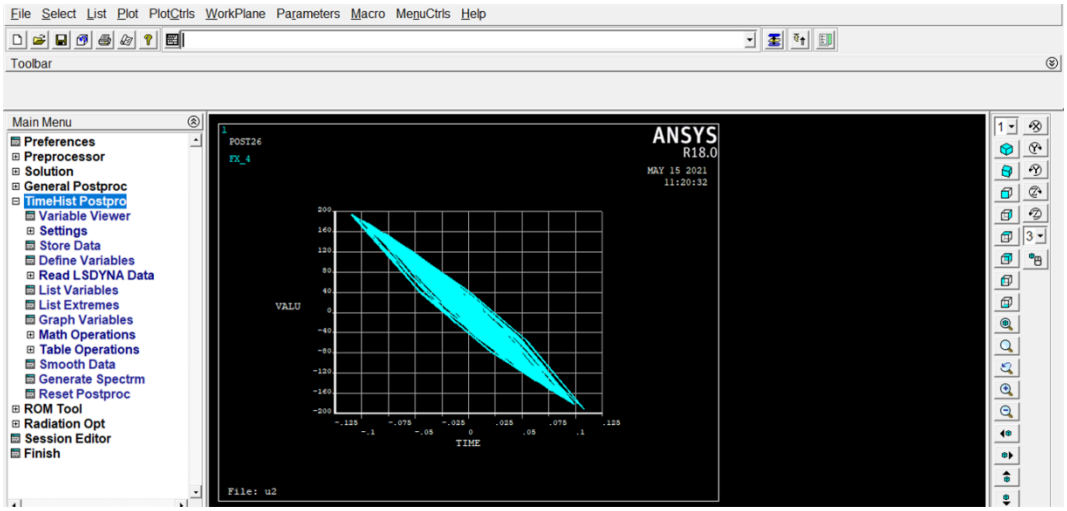
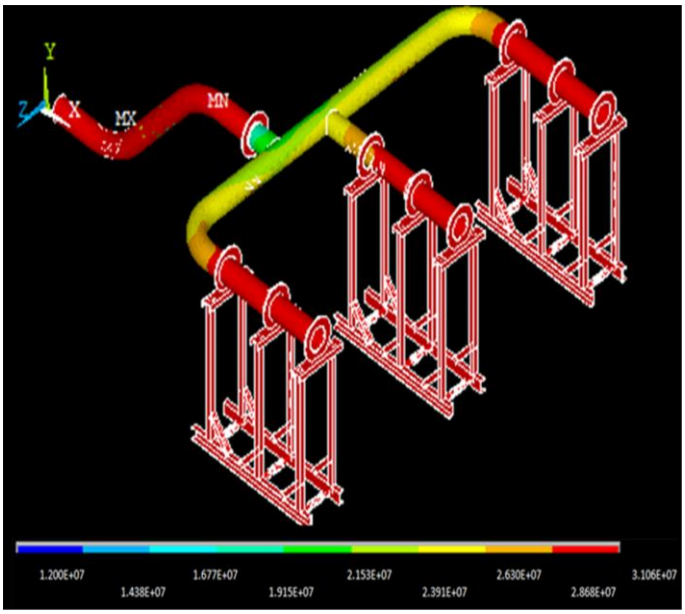


Figure 8. Modeling results for validation in the Ansys program

Comparing the load diagram with the laboratory and modeling results, it is observed that the results and results are almost the same, and the difference is very small.

Findings

In the following, the change of degree of freedom at the point of connection of SUPPORT to the station's foundation in the case of connection with metal bases and the case of connection with concrete bases according to Figure (9) is investigated.



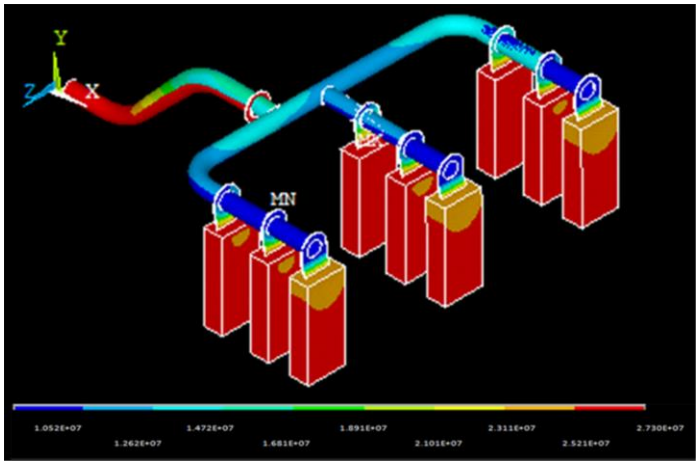


Figure 9. Comparison of stress changes in the PIPING system with metal and concrete supports

According to the studies, the findings reveal that concrete foundations have a notable impact on the stress distribution across the pipe system. In other words, in the sub-sections (distributor triangle), the highest stress was in the knee section, but its values are small. Plus, in the main knee part, the amount of stress has decreased, and according to the study, according to Table (2), the amount of stress in the use of metal support compared to concrete support has decreased by 11.46%.

Table 2. Comparison of stress in the PIPING system with metal and concrete support

Difference percentage	Stress (kg/m2)*E7	Model
-	3.106	Metal support
-11.46	2.75	Concrete support

In the following, the effect of changing the degree of freedom at the connection point of SUPPORT to the foundation on the seismic behavior of the SUPPORTING of the gas pressure reduction station is investigated. For this purpose, the type of connection of pipes to the ground in the form of metal and concrete supports with dimensions of 20 × 40 cm has been changed. The results show that the use of concrete support has increased the seismic bearing capacity of the structure. According to the studies performed according to Figures (10) and Table (3), the results show that the amount of final bearing capacity has increased by 16.89% compared to metal bases.

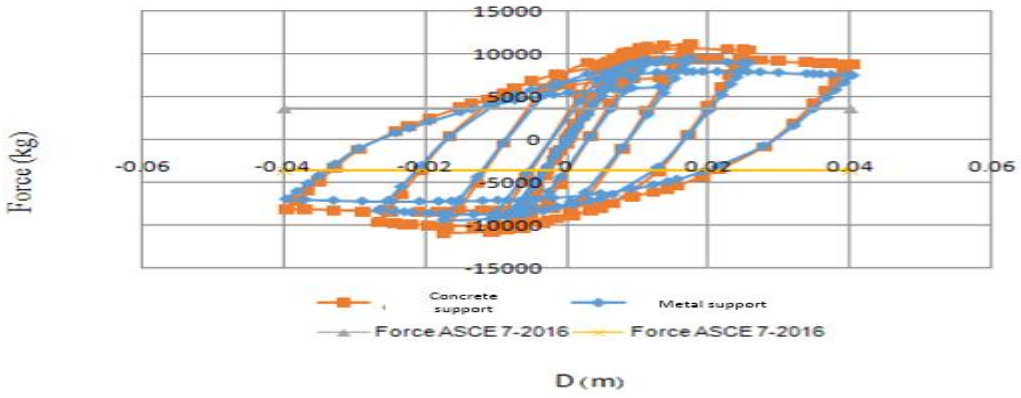


Figure 10. Comparison diagram of load to displacement ratio of PIPING system with concrete and metal supports

Table 3. Comparison of bearing capacity of PIPING system with change of under-pipe support

Difference percentage	Stress (kg/m2)*E7	Model
-	9498.09	Metal support
16.89	11109.319	Concrete support

Conclusion

The significance of the stability of gas stations during earthquakes in providing energy is unquestionable, and gas transmission pipelines are considered the energy arteries of the country, from production to consumption points. One of the factors that can influence the seismic behavior of the PIPING system is the pipe supports, which can affect the seismic behavior and distribution of stresses in the pipe. Because of the value of the matter, in this study, the numerical analysis of the parameters influencing the stress analysis of the supports in the gas station has been investigated as a case study using the high-pressure station type map implemented by the National Iranian Gas Company to present the factors affecting the design and strengthening of the PIPINGof the gas station system.

The findings revealed that the effect of changing the degree of freedom at the connection point of SUPPORT to the foundation on the seismic behavior of the SUPPORTING of the gas pressure reduction station in the form of metal support and concrete support has a notable impact on the seismic bearing capacity of the PIPING system. Studying the effect of changing the degree of freedom at the connection point of SUPPORT to the foundation on the seismic behavior of the SUPPORTING of the gas pressure reduction station by changing the type of connection of pipes to the ground in the form of metal support and concrete support shows that the final bearing capacity was 16.89% more effective than the use of metal bases. It is suggested that the angle of the elbow-shaped tubes out of the field on the failure of the knee-shaped tubes of the PIPING system of the high-pressure station be studied.

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