World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:14, No:7, 2020

Assessing the Impact of Underground Cavities on Buildings with Stepped Foundations on Sloping Lands

Masoud Mahdavi

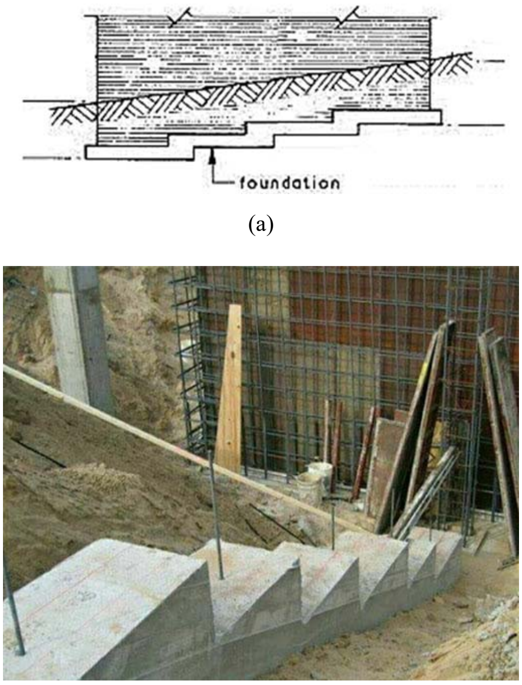
Abstract**—**The use of sloping lands is increasing due to the reduction of suitable lands for the construction of buildings. In the design and construction of buildings on sloping lands, the foundation has special loading conditions that require the designer and executor to use the slopped foundation. The creation of underground cavities, including urban and subway tunnels, sewers, urban facilities, etc., inside the ground, causes the behavior of the foundation to be unknown. In the present study, using Abacus software, a 45-degree stepped foundation on the ground is designed. The foundations are placed on the ground in a cohesive (no-hole) manner with circular cavities that show the effect of increasing the cross-sectional area of the underground cavities on the foundation's performance. The Kobe earthquake struck the foundation and ground for two seconds. The underground cavities have a circular cross-sectional area with a radius of 5 m, which is located at a depth of 22.54 m above the ground. The results showed that as the number of underground cavities increased, von Mises stress (in the vertical direction) increased. With the increase in the number of underground cavities, the plastic strain on the ground has increased. Also, with the increase in the number of underground cavities, the change in location and speed in the foundation has increased.

Keywords**—**Stepped foundation, sloping ground, Kobe earthquake, Abaqus software, underground excavations.

I. Introduction

URBAN land is declining sharply due to increased construction, and the use of uneven (including sloping) land is expanding every day. In urban environments, due to the existence of various structures, such as residential buildings, urban facilities, subways and sewers, there are many restrictions for being in the right place. Most of these spaces are excavated in the soil bed due to their proximity to the earth's surface. In such cases, structural stability is one of the most important factors in digging underground tunnels and requires careful evaluation. The existence of underground cavities, the number of which is increasing, has created many dangers. Underground cavities may be adjacent or under structures. These cavities tend to remove a mass of soil and rock and cause many changes in the equilibrium stress state around them. For this reason, the soils around the cavity are moved to balance the stress. If these cavities are created at shallow depths, their impact can spread to the surface of the earth and cause significant subsidence at the surface of the earth or even the collapse of the cavities [1], [2]. Zhang et al. reviewed the problems of deep tunneling in rock masses [2]. Huang et al. evaluated the effect of subsurface tunnels on building performance. The results showed that by creating an underground tunnel, the bending anchor at the ground level has increased sharply [3]. Nematollahi and Dias evaluated the effect of building underground parking lots on the behavior of everyday structures. The results showed that the construction of underground parking lots increases the movement of soil around the parking lot [4]. Ruiz et al. examined the effect of underground tunnel construction on ground vibration. The results showed that places that are directly above the tunnel have the greatest impact on the tunnel [5].

Masoud Mahdavi is M.Sc. in Civil Engineering-Structure, Graduated from Azad University (e-mail: Scientific.Achievements2030@gmail.com).



(a)

(b)

Fig. 1 Execution of stepped foundation in sloping lands

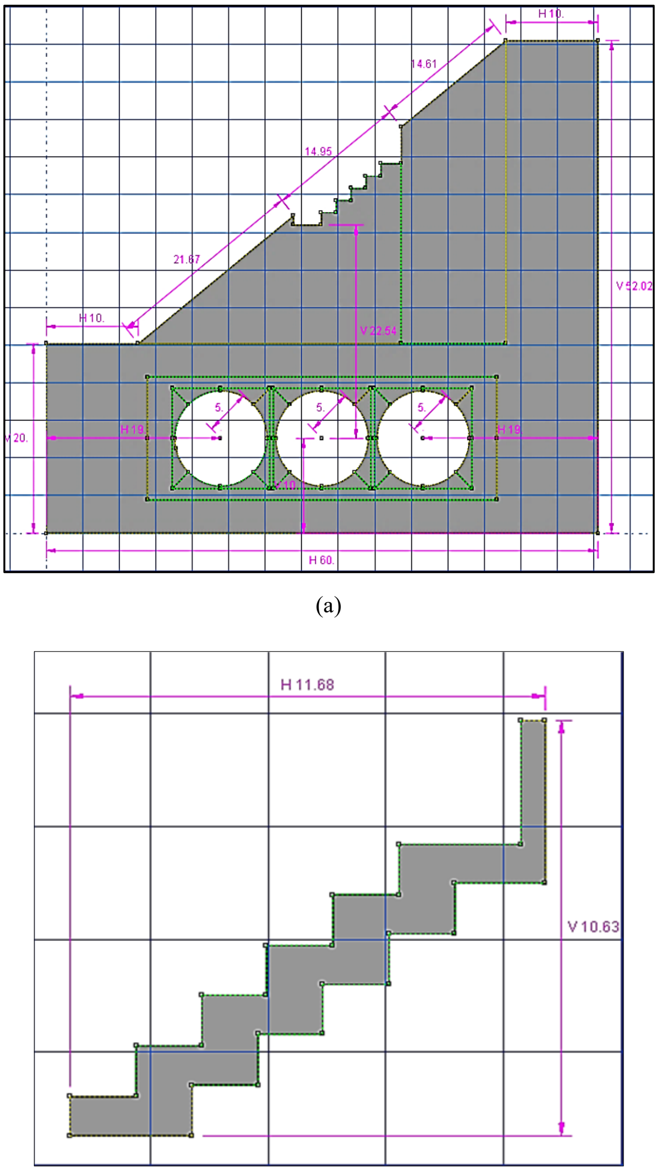
II. Methodology

A. Software

The present study was performed using Abaqus /cae 6.12.3 software.

B. Model Geometry

Modeling is done by combining the two elements of substrate soil and foundation. The bed has a 45 degree slope on which the stair foundation is placed. The dimensions of modeling are presented in Fig. 2.



(a)

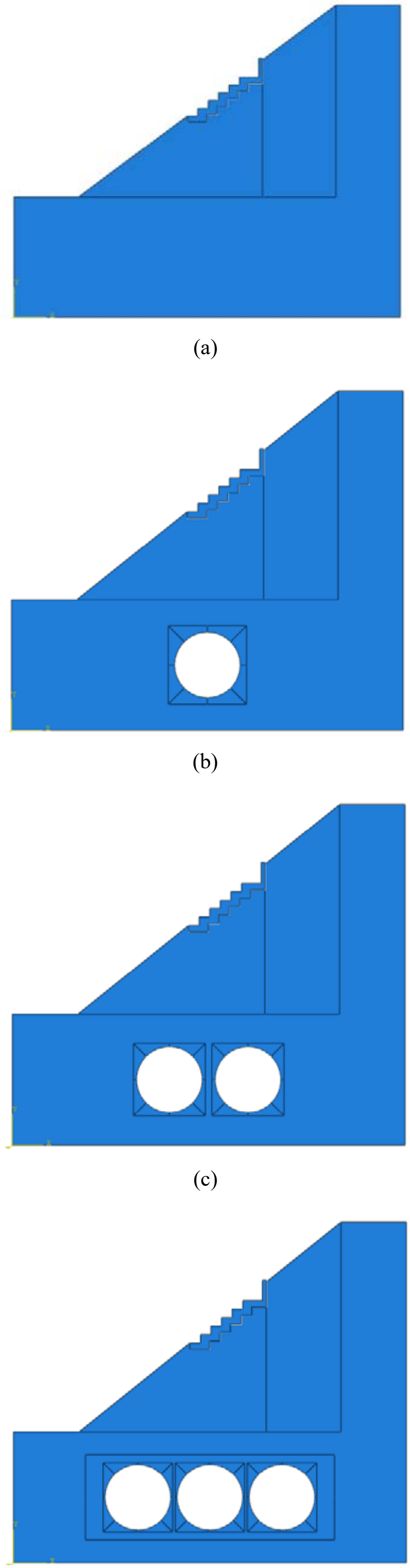
(b)

Fig. 2 Dimensions of models designed in the present study; (A) sloping land and (b) a stepped foundation

The models designed in the present study are named as shown in Fig. 3.

C. Materials

In the present study, two materials were used for modeling, the specifications which are presented in Table I. In soil modeling (dry sand), Drucker–Prager model is used, the specifications of which are presented in Table II.



(a)

(b)

(c)

(d)

Fig. 3 (a) SF model, (b) SFC1 model, (c) FC2 model and (d) SFC3 model

TABLE I
SPECIFICATIONS OF CONSUMABLES IN SOFTWARE MODELING

Materials	Density (kg per cubic meter)	Young modulus	Poisons ratio
Foundation (concrete)	2400	3×10^{10}	0.2
Soil (dry sand)	1550	3×10^{7}	0.25

TABLE II
SPECIFICATIONS OF DAGGER-PRAGER MODEL IN SOIL MODELING (LAND)

Angle of friction	Flowstress ratio	Dilation angle	Yield stress	Abs plastic strain
43.9	2400	3×1010	0.001	0

D. Loading

The geostatic model was subjected to a seismic load caused by the Kobe earthquake for 2 seconds. The Kobe earthquake acceleration is shown in Fig. 4. The weight load (due to gravity) and the hole water pressure (from the highest upgrade level of the geostatic model located at a height of 52.02 m) have been applied to the model.

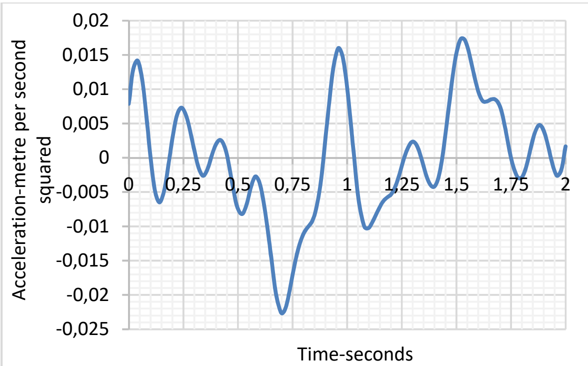
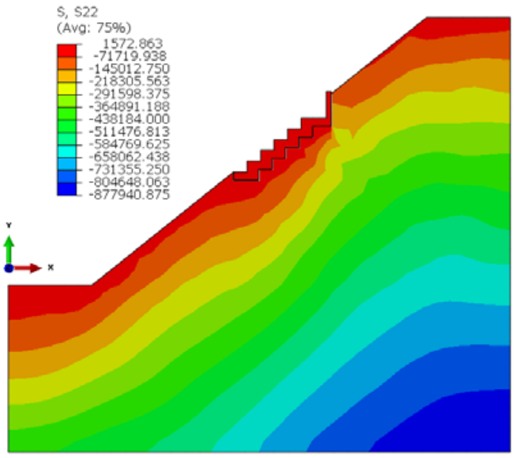


Fig. 4 Kobe earthquake acceleration

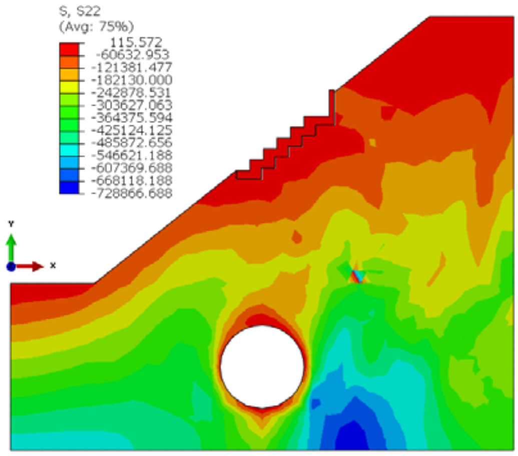
III. PRESENTING AND ANALYZING THE RESULTS

A. Von Mises Stress in the Vertical Direction

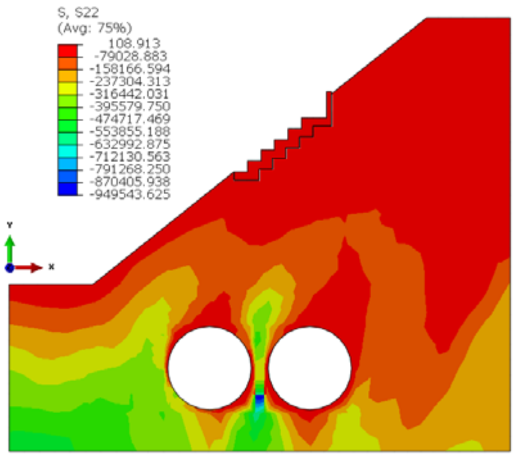
The results in Figs. 5 and 6 showed the von Mises stress in the vertical direction; the SF model has the highest tensile value with 1572 Pascal. The SFC3 has the highest compression value of 1125521 Pascal.



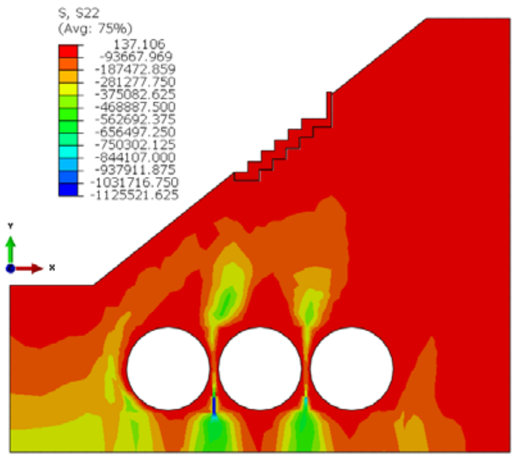
(a)



(b)



(c)

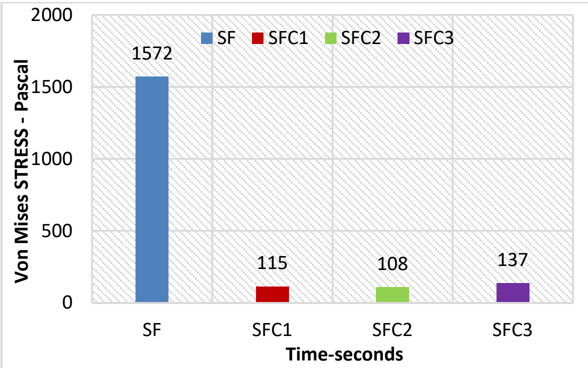


(d)

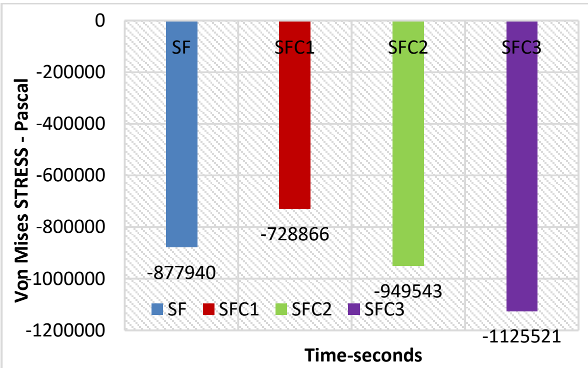
Fig. 5 Vertical stress of the table in vertical directions in SF, SFC1, SFC2 and SFC3 models

B. Plastic Strain

The results in Figs. 7 and 8 showed that with increasing number of underground cavities, the plastic strain in the soil (earth) has increased and has an upward trend. The lowest and highest values of plastic strain were created in SF (0.113 cm) and SFC1 (3.194 cm) models, respectively.



(a)

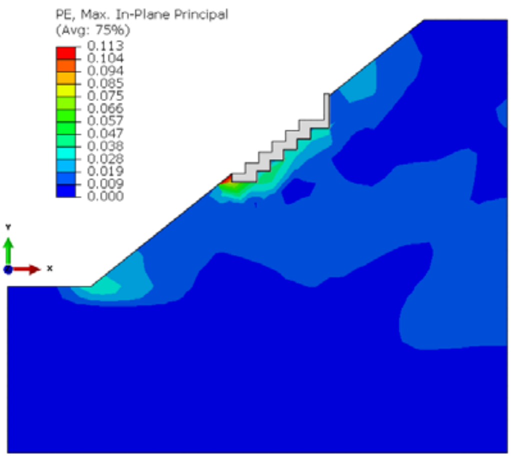


(b)

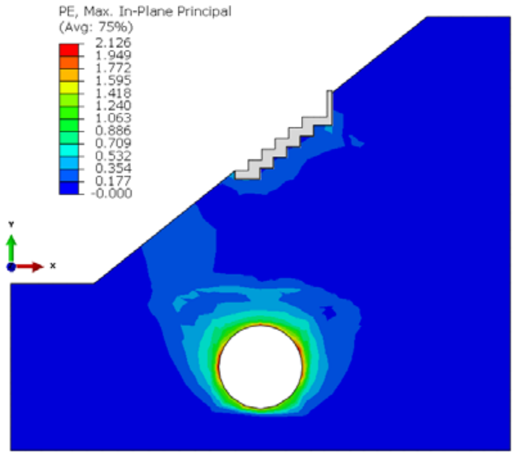
Fig. 6 Von mises stress curve; (a) tensile and (b) compressive, in vertical direction in SF, SFC1, SFC2 and SFC3 models under Kobe earthquake

C. Foundation Displacement

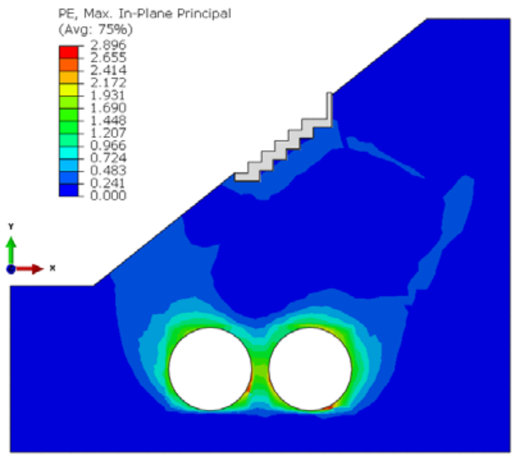
The results in Fig. 9 showed that with the increase in underground cavities, the displacement in the foundation has increased significantly. The most change has been made to the SFC3.



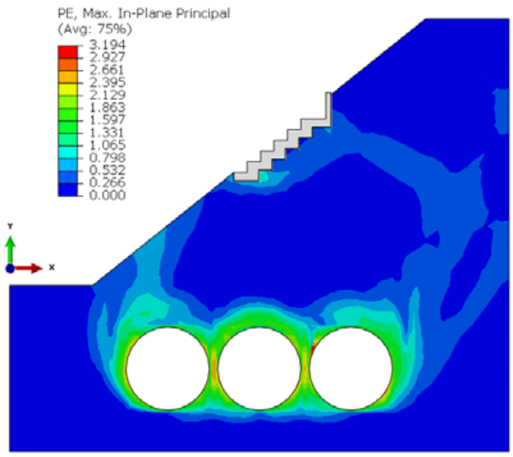
(a)



(b)



(c)



(d)

Fig. 7 Plastic strain in SF, SFC1, SFC2 and SFC3 models

D. Foundation Speed

The results in Fig. 10 showed that with increasing the number of underground cavities, the speed in the foundation has increased significantly. The highest speed is created in the SFC3 model.

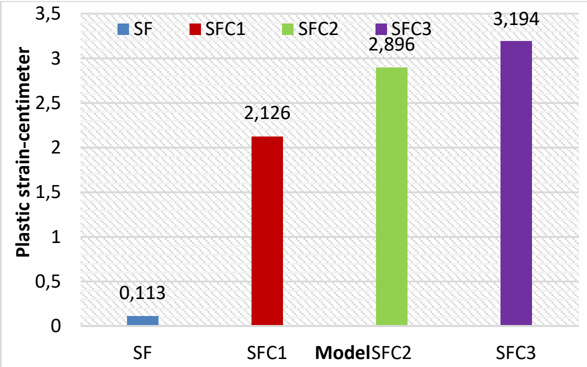


Fig. 8 Curve of the highest amount of plastic strain in SF, SFC1, SFC2 and SFC3 models under Kobe earthquake

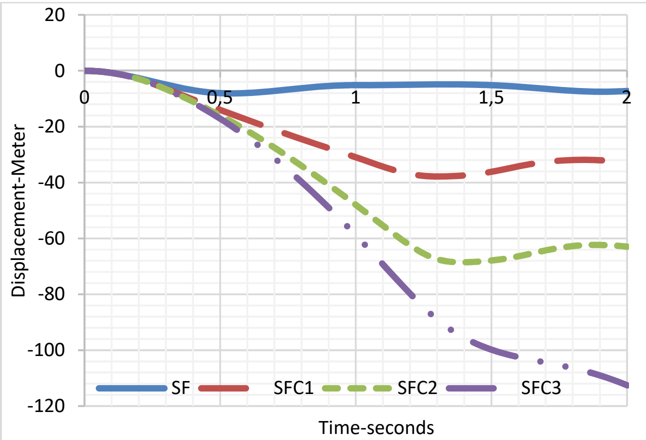


Fig. 9 Displacement curve in SF, SFC1, SFC2 and SFC3 models

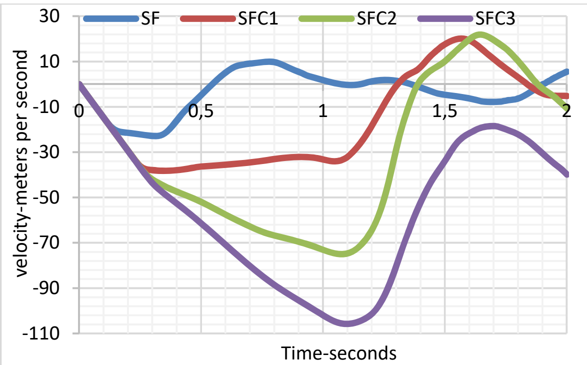


Fig. 10 Speed curve in SF, SFC1, SFC2 and SFC3 models

IV. Conclusion

With the increase in the number of underground cavities, von Mises stress (in vertical direction) increases.

With the increase in the level of underground cavities, the plastic and permanent strain in the bed soil has increased significantly. Most plastic strain is created around the underground cavity, but the amount of plastic strain in the foundation has also been greatly increased.

With the increase in the level of underground excavations, the location of the foundation has increased significantly.

With the increase in the level of underground cavities, the speed of the foundation has increased significantly.

References

[1] V. Guglielmetti, P. Grasso, A. Mahtab, S. Xu, "Mechanized Tunneling in Urban Areas: Design Methodology and Construction Control", (V. Guglielmetti, Ed.) London: Taylor And Francis Elibrary, ISBN: 978-0-203-393851-5 (Ebook), 2007.

[2] W. Zhang, L. Han, X. Gu, L. Wang, F. Chen, H. Liu, "Tunneling and Deep Excavations in Spatially Variable Soil And Rock Masses: A Short Review", Underground Space, Pii: S2467-9674(20)30007-6, 2020.

[3] X. Huang, W. Liu, Z. Zhang, Q. Zhuang, Y. Zhu, Qi Wang, C. Y. Kwok, S. Wang, Structural Behavior of Segmental Tunnel Linings for a Large Storm Water Storage Tunnel: Insight from Full-Scale Loading Tests, Tunnelling and Underground Space Technology 99 (2020) 103376, 2020.

[4] M. Nematollahi, D. Dias, Interaction between an Underground Parking and Twin Tunnels – Case of the Shiraz Subway Line, Tunnelling and Underground Space Technology 95 (2020) 103150, 2020.

[5] J. F. Ruiz, P. J. Soares, P. Alves Costa, D. P. Connolly, "The Effect of Tunnel Construction on Future Underground Railway Vibrations", Soil Dynamics and Earthquake Engineering 125 (2019) 105756, 2019.