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Yığma Tarzda İnşa Edilecek Yapılarda Sonlu Elemanlar Metodu İle Hacim ve Yük Analizleri Üzerine Bir İnceleme

A Study on the Finite Element Method and Volume and Load Analysis in Buildings to be Constructed in Masonry Style

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ÖZET

Arazinin imar planlarındaki durumuna göre ister normal ister tarihi kent dokusuna uygun şekilde tasarlanması uygun görülen bir yapı modeli oluşturulmak istenirse mutlaka birtakım fizibilite çalışmalarına ihtiyaç vardır. Özellikle tarihi bir yapının eski dokusuna uygun şekilde restore çalışması ya da bağ bahçe alanlarında H=6,50 metre gibi 2 ya da 3 katlı bir bina yapımında zemin ve üst katın taş olarak kargir yapı şeklinde inşaat projelerinin hesaplarında sonlu elemanlar yöntemi ile bir modelleme yapılarak yapının hacimsel anlamda ölü yük, hareketli yük, toprak yükü, su yükü gibi yük kombinasyonları hesaplanır. Kargir yapının zemin ve üst katındaki taş temelinde duvar analizlerine bakılır. Sonlu elemanlar yöntem olarak çalışmada uygulanmıştır. Sonlu elemanlar bağlantı ve düğüm noktaları oluşturarak bir yapının modellenmesini meydana getirmektir. Bu metotla birlikte özellikle SAP programından yararlanılır. Çalışmamızda örnek bir yığma tarza yapılacak yapıda tüm yük kombinasyonlarının nasıl olması gerekliliği ve zemindeki taş temelin duvar yüklerinin asgari nasıl olacağı hakkında analiz sonuçlarına bakılmıştır.

Anahtar Kelimeler: Yığma Yapılar, Sonlu Elemanlar Metotu, Hacim ve Yük Hesabı

ABSTRACT

If it is desired to create a building model that is suitable to be designed according to the situation of the land in the zoning plans, whether it is normal or in accordance with the historical urban texture, some feasibility studies are definitely needed. Especially in the restoration work of a historical building in accordance with the old texture or in the construction of a 2- or 3-storey building such as H = 6.50 meters in vineyard or garden areas, the ground and upper floor are stone, masonry construction projects, by making a modelling with the finite element method in the calculations of the structure. In the volumetric sense, load combinations such as dead load, live load, soil load, water load are calculated. Wall analysis are made on the stone foundation on the ground and upper floors of the masonry building. Finite element method was applied in the study. Finite elements are creating the modelling of a structure by creating connection and nodal points. With this method, especially the SAP program is used. In our study, the analysis results about the necessity of all load combinations and how the wall loads of the stone foundation on the ground will be minimum in a building to be built in a masonry style were examined.

Keywords: Masonry Structures, Finite Element Method, Volume and Load Calculation

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1. INTRODUCTION

The compressive strength of a masonry structure is high, but it has low tensile strength. This case indicates that masonry structures are very vulnerable under tensile stresses (Şahin, 2019). The analysis and modelling of the historical building structures require tough and profound investigations. Because the general behavior of such structures depends on a great number of factors such as the behavior of singular walls, soil properties, rigidity and material properties (Calderoni, Ghersi et al., 1994). These factors vary in the structures (Şahin, 2019). Micro, macro and meso modeling methods are widely used as modeling techniques. Macro modelling is preferred since it is easier to think of composite material by homogenizing the masonry building elements (Kocaman, Kazaz et al., 2008). In the master's thesis called "Computer Aided Analysis of Historic Structures; Example of Patara Antique City Theatre Stage Structure", The structural modelling and analyses were performed using the program SAP2000 (Özdemir, H., 2018). Macro modelling was preferred as the modelling technique. As a result of the analysis, the weaknesses of the building were determined and some precautions were proposed. Also, the comments were made about the earthquake movement of the structure (Şahin, 2019). Any frame system of both horizontal and vertical loads acting on the structure masonry structures to structures that are carried only by walls, not by we can say (Demirkan, 2014). Masonry structures can be built from stone, brick, adobe and similar materials with or without mortar (Demirkan, 2014). Steel, in terms of carrying out the load-bearing role of the walls, they differ from reinforced concrete and wooden structures (Bayraktar, 2011). In masonry structures, we can name the load-bearing walls according to the construction techniques, the size and type of the material used, the arrangement of the elements used and similar variables (Demirkan, 2014).

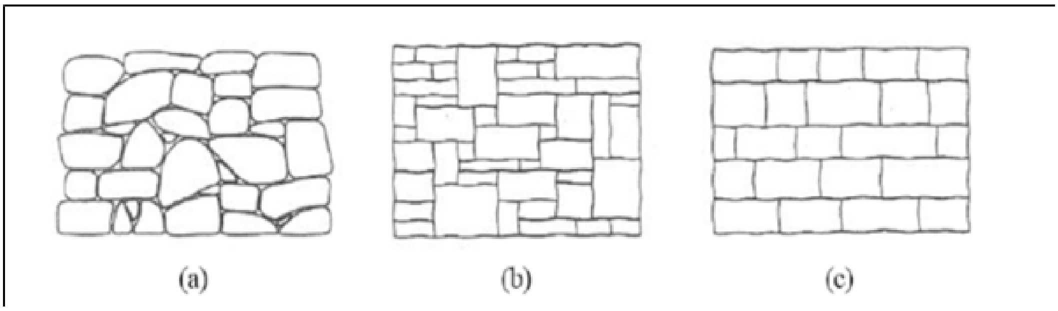

Figure 1. Masonry stone walls a) Rubble stone, b) Cut stone, c) Lined Cut Stone (Lourenço, 1998).

When examining masonry structures, some differences between them and other structures should be known. For example, vertical loads in masonry structures are usually only 10-15% of the vertical bearing capacity of the load-bearing wall. Damages in masonry structures are generally caused by horizontal loads. Cracks due to ground settlements, off-axis loading of the wall and movements can also be shown among the reasons (Arun, 2005).

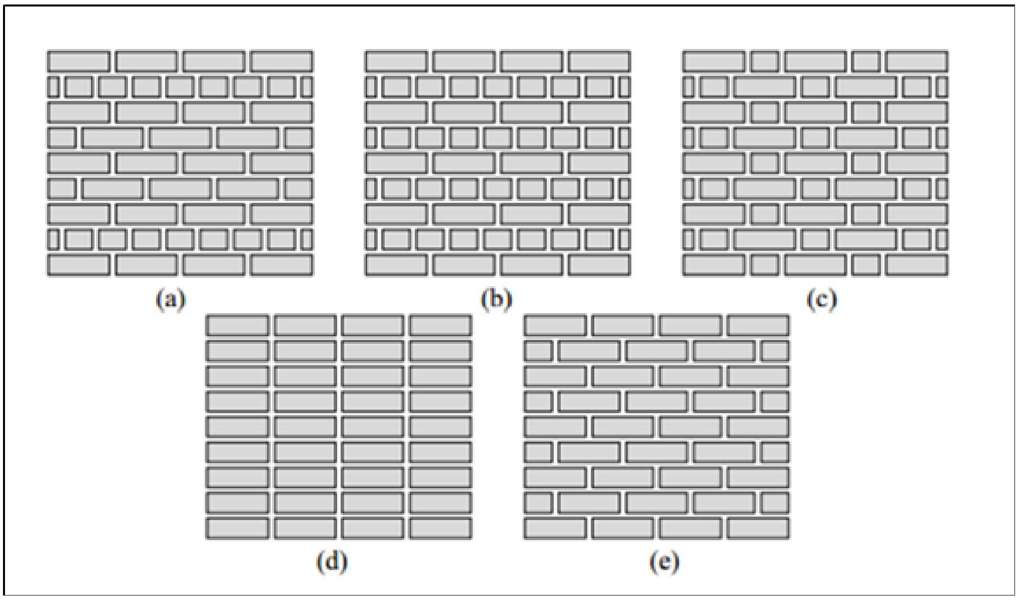

Figure 2. Masonry brick walls a) simple or American b) cross or English c) filament d) straight e) staggered (Lourenço, 1998;Demirkan, 2014).

It would be wrong to consider the materials used in masonry structures as isotropic materials. In addition, it can be interpreted that the deformation of a load-bearing wall, which can be considered as a heterogeneous mixture of mortar and stone, will differ according to the material under force from different directions. With these features, load-bearing walls are anisotropic or orthotropic elements (Heyman, 2006). Determining the mechanical properties of the load-bearing wall system close to their actual values is the most important step in the accuracy of the work done in masonry structures (Demirkan, 2014). Although masonry structures are an old type of construction technique, nowadays they have general validity especially for the vineyard or garden areas to be built in the adjacent areas outside the zoning.

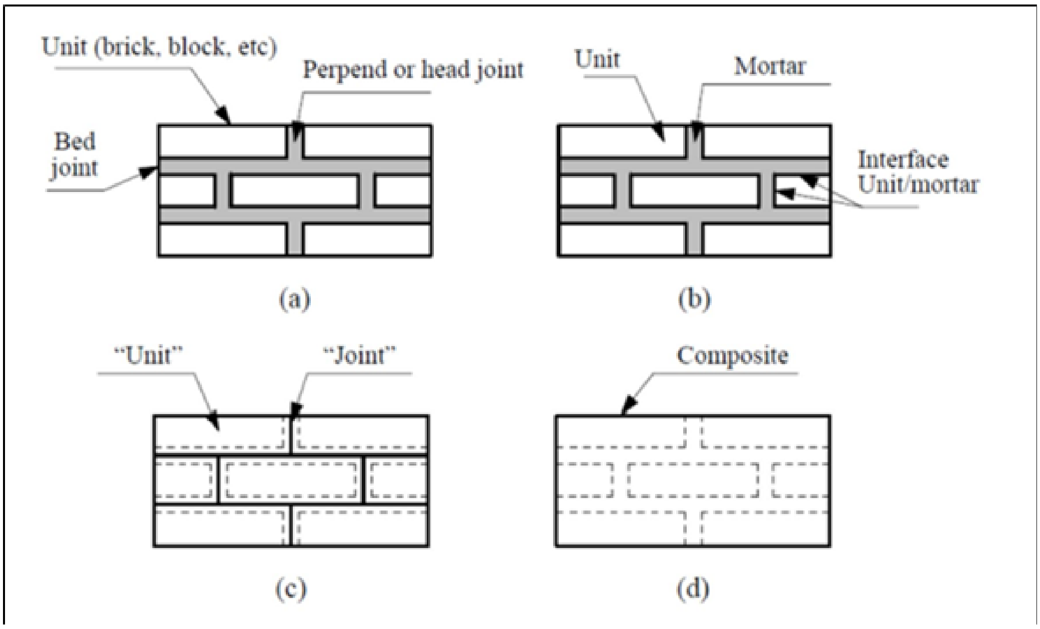

Figure 3. Modelling methods a) wall example b) micro model c) simplified micro model d) macro model (Lourenço, 1996;Demirkan, 2014).

For this reason, the form of construction in lands such as vineyard or garden areas is usually in the form of piles. It is made by calculating the static and dynamic loads on the foundations of masonry structures and on the upper floors. From time to time, the ground is made of masonry and the upper floors are masonry, in mixed structures.

2.MATERIAL AND METHOD

Masonry structures include mortar and units such as bricks, blocks, adobes, ashlars and irregular stones (Lourenco, 2002). Mortar is a material used in masonry construction to fill the gaps between the bricks and blocks and bonds units together to present a collective behavior of the elements of the masonry structure member (Şahin, 2019). The main purpose of the use of mortar is to link structural units with each other. Also, the mortar helps to distribute the loads on the structural elements and it protects the structure against external influences (Satongar, 1994). The mortar emerged with the use of brick and adobe as construction material. In Romans period, lime mortar came into use for the first time. In Seljuk and Ottoman architecture, khorasan mortar was used (Saraç, 2003).

The finite element method (FEM) is a numerical technique for engineering problems. These engineering problems include deformation and stress analyses of aircraft, automotive, building and bridge structures, fluid flow, seepage, field analysis of heat flux and so on (Teomete, 2004;Şahin, 2019). Most of these processes are expressed by using partial differential equations. Finite element method cuts a structure into several elements. Then reconnects elements at "nodes" as if nodes were pins or drops of glue that hold elements together (Şahin, 2019).

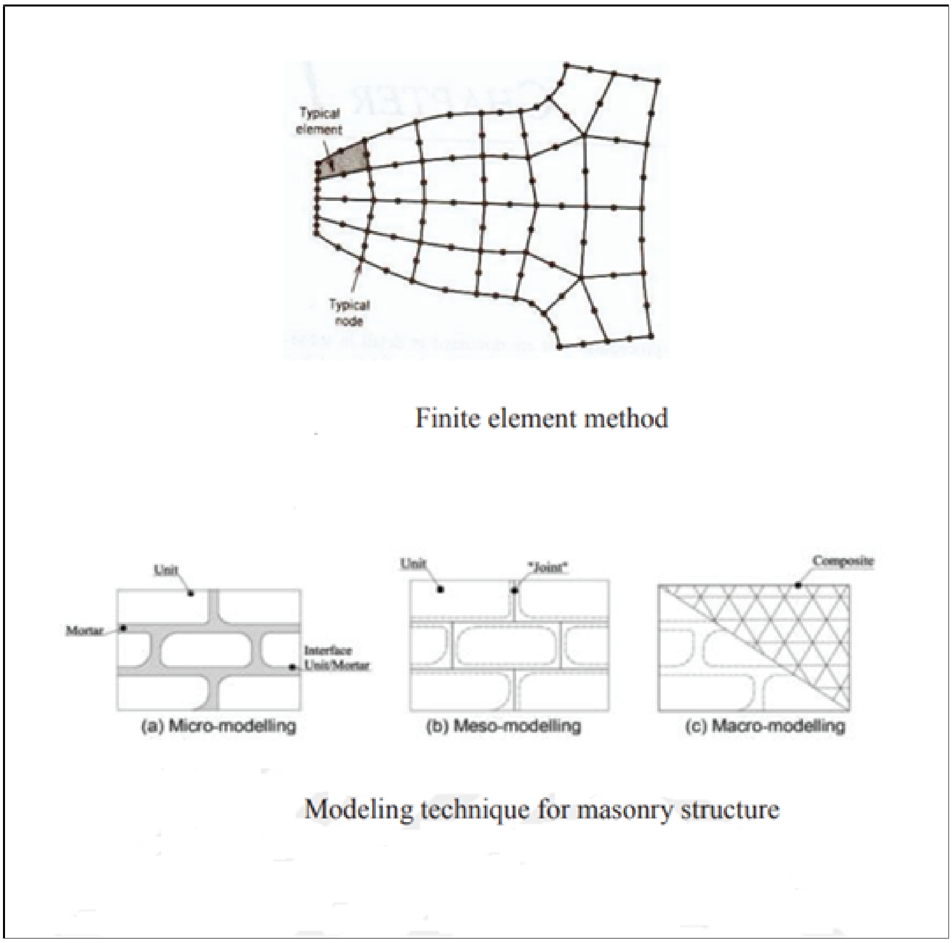

Figure 4. Finite Element Method (Weck and Kim, 2004; Lourenco, 2002;Şahin, 2019).

Although the label finite element method first appeared in 1960, when it was used by Clough (Clough RW, 1960). In a paper on plane elasticity problems, the ideas of finite element analysis date back much further (Taşkaya, 2021). The first efforts to use piecewise continuous functions defined over triangular domains appear in the applied mathematics literature with the work of Courant in 1943 (Courant R, 1943). Regardless of the type of building, either masonry, stone or mixed finite element method, the minimum and maximum required number of points is determined and the curtain concrete load that will withstand dead, wind, earthquake, iron connection points, beam and concrete accents are determined. The best masonry calculation points are determined with triangular or different geometric approaches.

3. FINDINGS

In our study, in a sample masonry building study, first of all, the nodal points of the structure to be created are created so that the cubage calculations can be made. Solutions of the building to be built in masonry SAP2000 program obtained with the help of The finite element model created in this program can be seen in Figure 5 and has a total of 8269 nodes, 264 3D frame elements, 1445 shell elements and 4275 3D solid media elements.

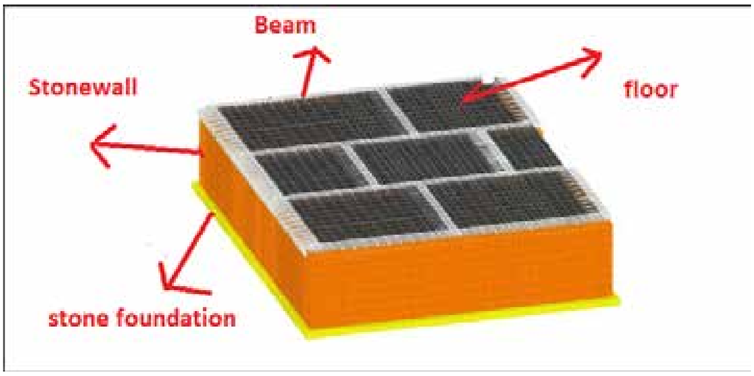

Figure 5. Finite element model of the sample building

The calculations for the masonry building's stone foundation and wall beams and slabs are made according to the nodal points estimated with this finite element. As can be seen in Figure 5, it is seen from an interior section view how the basic connection points of the masonry building are connected. An average two-story building example has been calculated finitely with only about 4000 connections on the ground. It is appropriately determined that this is the amount to withstand all environmental loads.

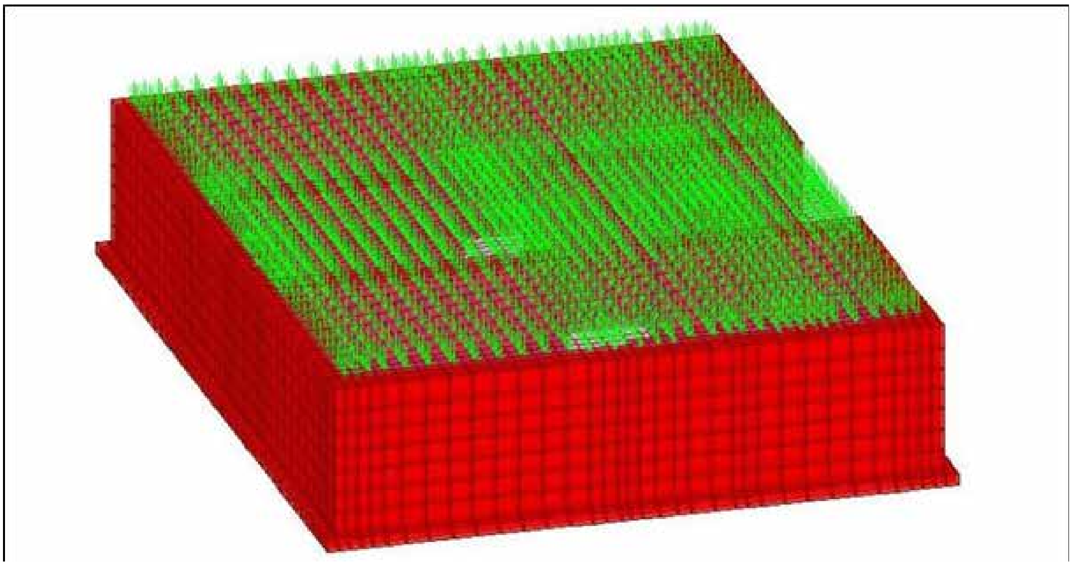

Figure 6. Dead Load Status Display

The weight of floors, walls and beams is automatically taken into account in the SAP2000 program by multiplying the unit volume by the unit volume weight. For this reason, only the weights of the additional structural elements per unit area are taken into account under the dead load heading.

Coating+plaster 2.10 km/m^2

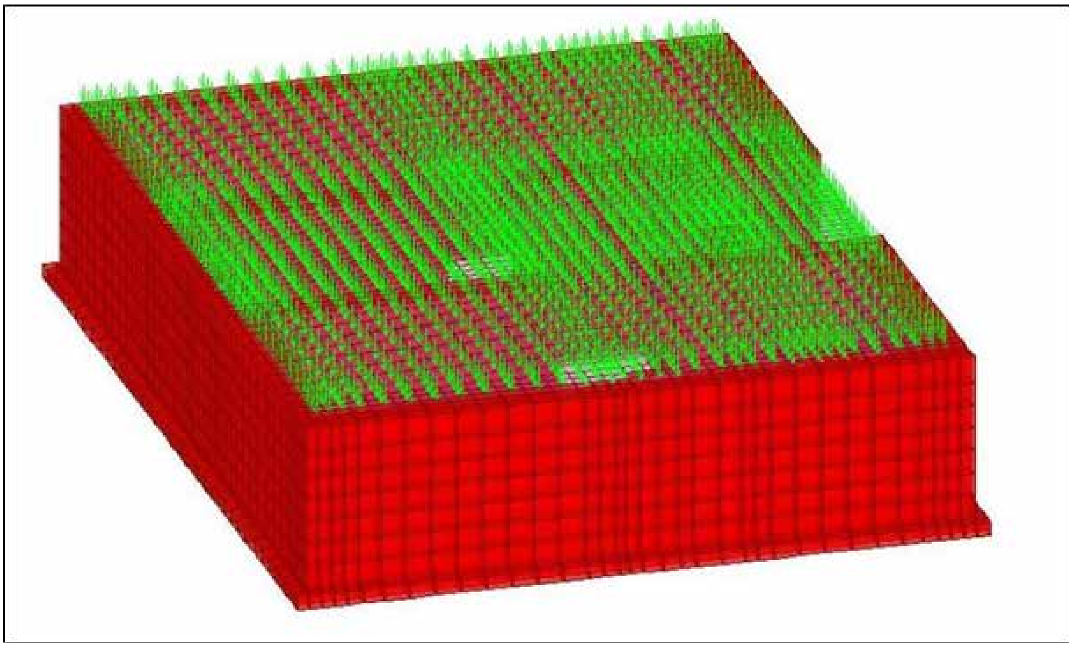

Figure 7. Live load status display

2.0 kn/m^2 as live load taken and effected on the upper surface of the floor. It is seen how many point clouds will be connected from the program to the ground floor for which the force extreme is determined. Iron connection points are shown in green inside the wall type, which is determined in red on the outer section assembly.

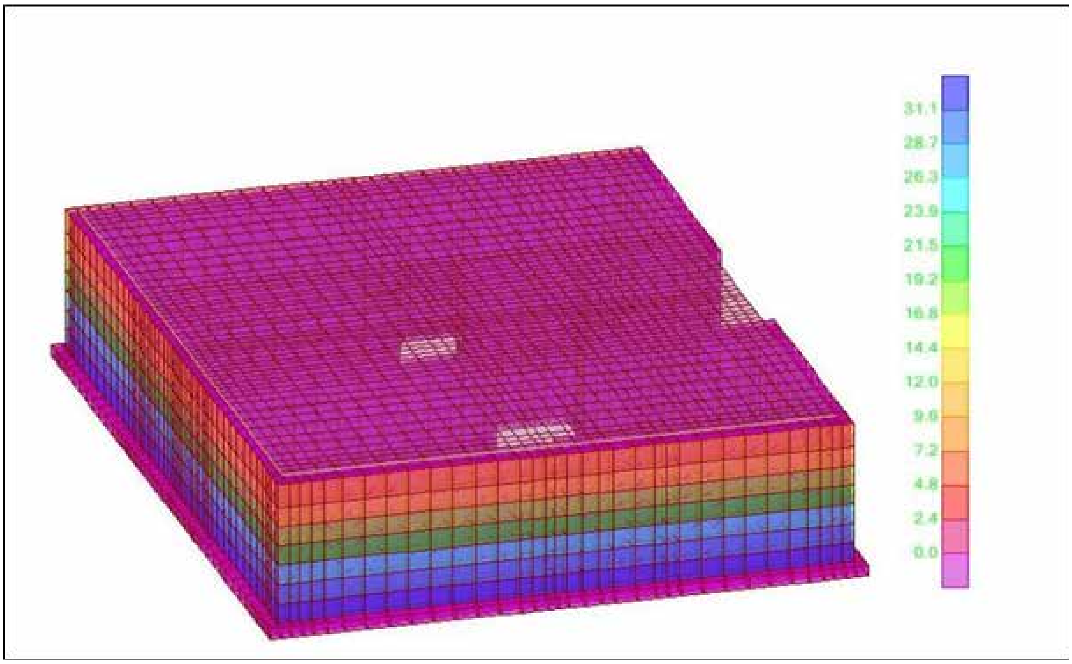

Figure 8. Ground Load Status

Unit volume weight of the soil is 18 km/m^3 and Internal friction angle is 30^o taking the active soil pressure coefficient Ka, Ka= 0.333 was calculated. This value is effected on the side surfaces. At the same time, since 1.3 m high soil fill affects the reinforced concrete floors, it is calculated that a load of 1.3x18=30.6 kn/m^2 will affect the floor surfaces when this height is taken into account. In the ground load situation, the range of how the force will act as newtons in a 31 unit area from zero is determined.

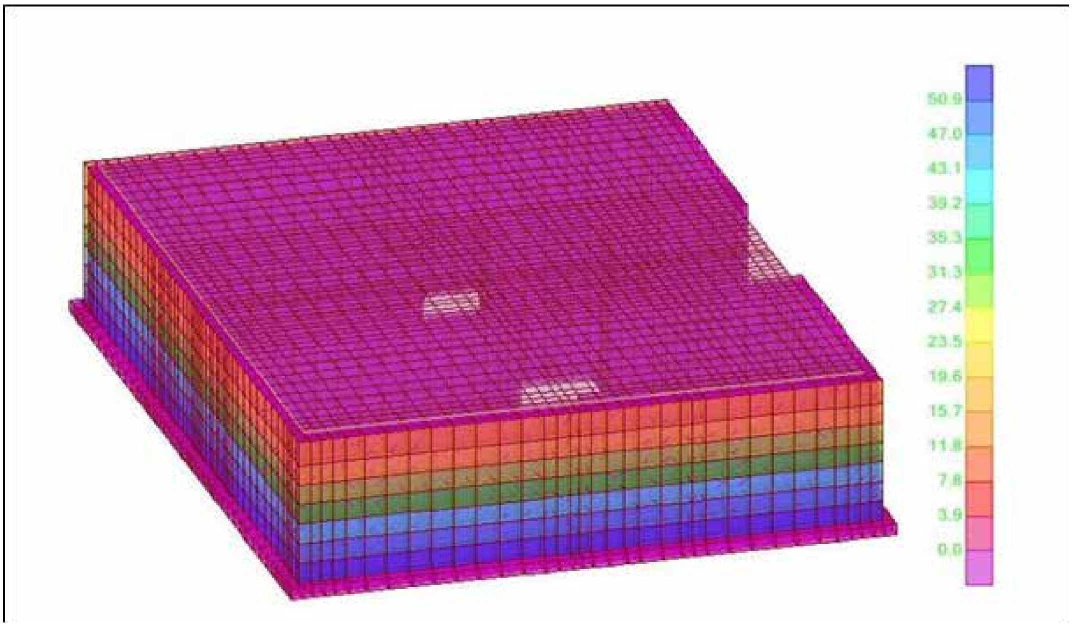

Figure 9. Water Load Status

The unit volume weight of the water was taken as 9.81 km/m3, and it was effected as groundwater on all surfaces with soil.

Load Combinations;

COMB 1:1.40 G+1.60 Q+ 1.60H+ 1.40 S
COMB 2:1.00 G+ 1.60 H
COMB 3:1.00 G+1.00 Q+ 1.00H+ 1.00 S+1.00 Ex
COMB 4:1.00 G+1.00 Q+ 1.00H+ 1.00 S+1,00 Ey
COMB 5:0.90 G+1.00 Ex
COMB 6:0.90 G+1.00 Ey
COMB 7: Envelope values of all loading combinations

With the determination of the load combinations values, together with the modelling of the nodal points of the masonry example building, the combination of the beams, the floor points, the water, dead, soil, etc. in the formation of the stone foundation and the wall. By calculating the loads, cubage and coordinate data are obtained. Especially in winter and summer transitions, it can be understood from simple formulas how to find the water load status of concrete as a result of certain combinations. In these formulas, it is seen that the area amount of the structure, the amount of height that will occur on each floor and above the ground, and the gravity acceleration will be obtained from the positional X and Y coordinates on the geoid in the light of the parameters.

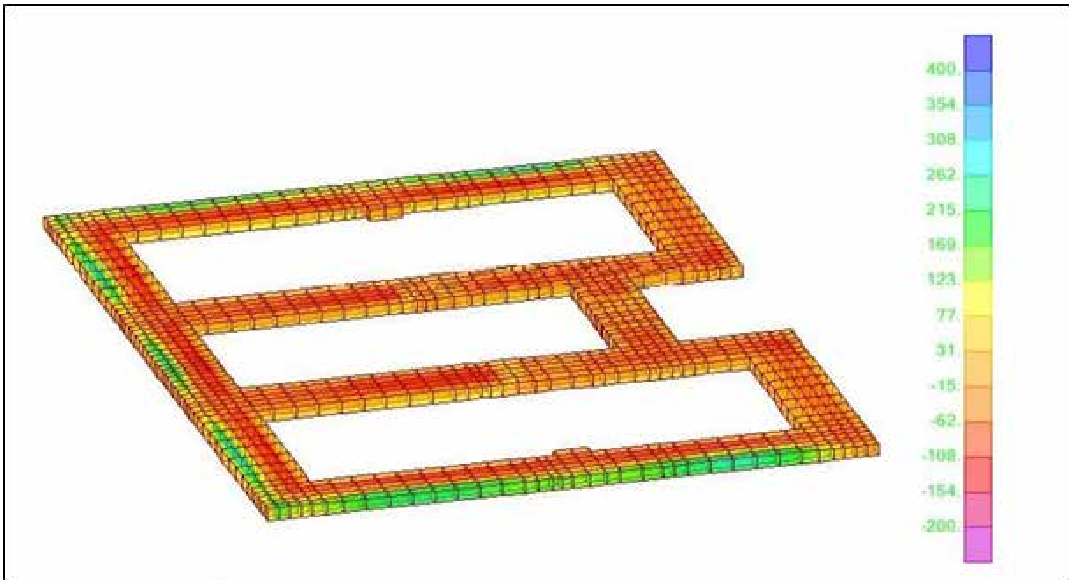

Figure 10. Maximum stresses obtained for KOMB-7 on stone foundation

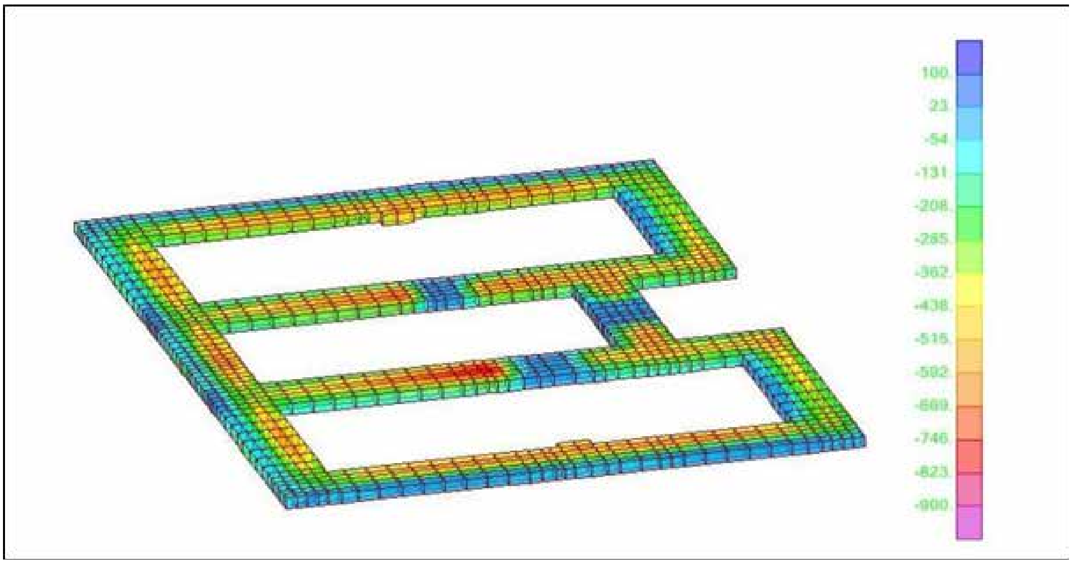

Figure 11. Minimum stresses obtained for KOMB-7 on stone foundation.

The maximum and minimum principal isothermal stress curves obtained from the stone foundation are seen. Considering these curves, 345 kn/m^2 tensile stress was obtained as -881 kn/m^2. Figure 14 shows the homogenized values obtained for the foundation. It is seen that the values below are obtained. In the figures, it has been worked out that the range of the force per unit area to be applied to the tabs on each floor in a maximum and minimum manner will be 400 kn/m^3, and in the opposite case, it may occur up to -900s. This is especially the case from the SAP image, where the connection points overlap on the basis of height.

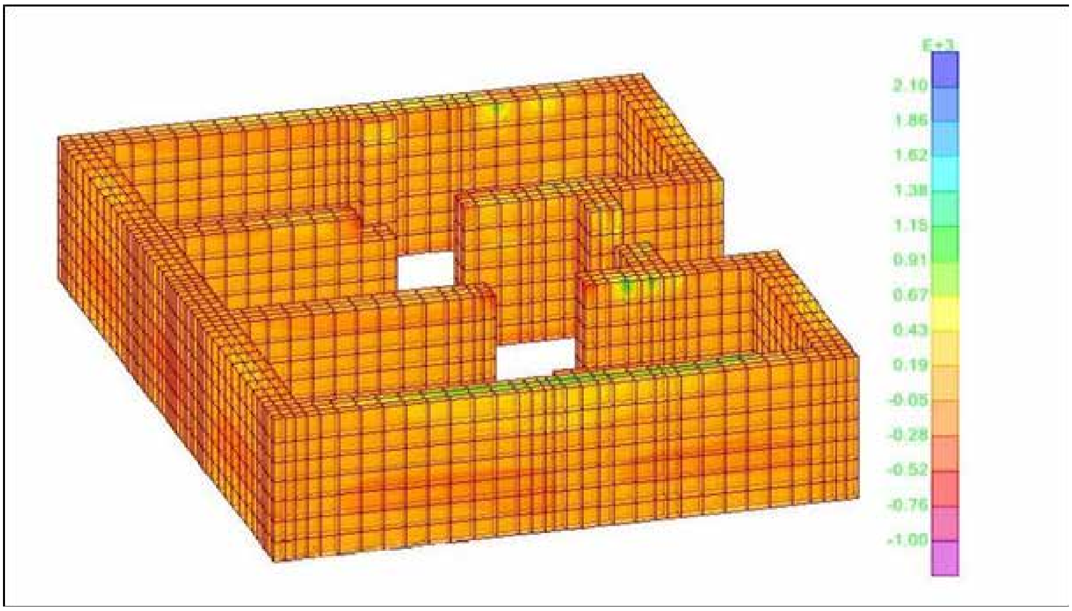

Figure 12. Maximum stresses obtained for KOMB-7 in stone walls

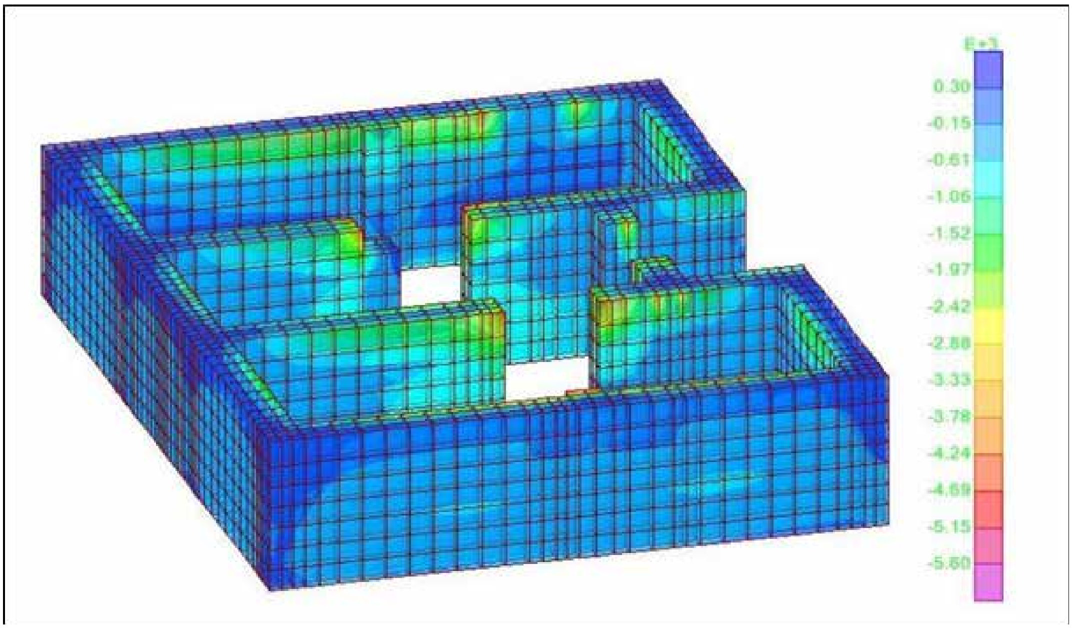

Figure 13. Minimum stresses obtained for KOMB-7 in stone walls

Maximum and minimum principal co-stress in stone walls curves are shown. Considering these curves, 2073.86 kn/m^2 tensile stress was obtained as -5582.3 kn/m^2. From the two figures, the maximum and minimum overlap rates between the masonry walls are processed and how it will be affected by any external factor is processed. The range of energy from the relationship proportional to the force is shown and graphed with different colors.

Table1. Building slab reinforced concrete calculations

Area EL. No.	Loading	F11	F22	V13	V23	M11	M22	Mmax
		Kn/m	Kn/m	Kn/m	Kn/m	Kn-m/m	Kn-m/m	Kn-m/m
1	KOMB	-34.3	115.7	20.4	-158.8	20.2	112.3	112.3
2	KOMB	-34.0	-113.9	20.4	-192.3	27.5	118.9	118.9
3	KOMB	-58.7	114.3	20.4	-178.4	24.8	114.3	114.3
4	KOMB	-58.9	-113.2	20.8	-145.5	22.6	115.6	115.6
5	KOMB	-34.3	115.8	20.9	-145.5	23.5	117.8	117.8
6	KOMB	-35.7	-116.8	20.1	-172.3	26.8	114.5	114.5
7	KOMB	-57.3	-114.2	23.0	-172.8	26.6	113.2	113.2
8	KOMB	-55.9	112.9	22.5	-165.5	26.6	118.8	118.8
9	KOMB	-59.9	112.9	22.6	-168.2	24.7	122.3	122.3
10	KOMB	-58.5	112.9	22.5	-169.3	24.7	114.6	114.6
11	KOMB	-57.9	-115.4	22.3	-172.3	29.8	115.2	115.2
12	KOMB	-59.3	-115.4	-21.4	-154.3	29.7	112.3	112.3
13	KOMB	-55.7	113.8	22.3	-112.4	29.4	111.2	111.2
14	KOMB	-56.0	112.4	21.5	-115.5	24.6	110.8	110.8
15	KOMB	-59.0	-112.6	21.0	-114.3	24.5	112.4	112.4
16	KOMB	-58.7	114.3	22.1	-114.3	25.8	113.3	113.3
17	KOMB	-59.4	117.6	22.1	-116.3	21.3	111.1	111.1
18	KOMB	-58.7	111.2	22.1	-174.8	21.3	114.5	114.5
19	KOMB	-56.3	-115.4	23.3	-152.3	22.6	112.9	112.9
20	KOMB	-57.0	114.2	23.3	-152.6	22.8	115.5	115.5
21	KOMB	-59.5	-116.8	22.8	-152.8	22.6	114.3	114.3
22	KOMB	-59.2	112.4	22.8	-142.3	22.5	117.2	117.2
23	KOMB	-55.0	114.1	22.8	-142.8	21.3	112.3	112.3
24	KOMB	-55.3	-115.8	21.1	-140.9	21.3	115.6	115.6
25	KOMB	-57.1	114.3	21.1	-140.9	22.4	113.3	113.3
26	KOMB	-56.0	111.8	21.1	-142.8	25.1	116.6	116.6
27	KOMB	-53.4	-112.3	22.5	-142.3	25.0	122.3	122.3
28	KOMB	-58.6	115.9	22.4	-145.6	26.1	121.2	121.2
29	KOMB	-54.2	112.6	22.4	-145.9	26.3	115.3	115.3
30	KOMB	-52.6	-115.3	21.2	-142.7	26.4	114.2	114.2
31	KOMB	-52.9	-111.4	21.2	-148.9	25.6	114.8	114.8
32	KOMB	-54.3	112.9	22.2	-142.9	24.3	112.3	112.3
33	KOMB	-58.6	111.1	21.2	-142.9	24.3	111.7	111.7
34	KOMB	-59.0	112.4	21.3	-145.6	25.9	112.4	112.4
35	KOMB	-55.2	-118.7	20.4	-145.6	27.3	115.5	115.5

With the help of bases and angles found by determining the coordinates of horizontal and vertical distances such as Xp and Yp with the joint points created by the finite element method, the slabs are formed on an area basis and their value in strength is determined. The push and pull forces of 35 points and the most necessary connection points, and the values of the connection points in terms of volume and area, the parameter values of each point in newtons of the force in terms of masonry structure in an example two-storey building are processed.

4.CONCLUSION

In the examples of buildings made in masonry style, first of all, how many floors will be built, some parameters such as finite element method or any method, such as micro or macro zoning technique should be examined. In these, especially columns, beams, foundation and side instruments should be determined. With SAP, the need for nodal points should be determined and the acceleration and forces of these nodal points should be determined. From the point of view of cartography, modelling should be done by establishing base stations between the distances from the coordinates of the node points. With this modelling, floor calculations must be made by taking into account the maximum and minimum tension forces of the load types of the structure. In our study, the calculation of loads such as water, volume, soil, dead load was shown with load combinations. Our suggestion is to give an example of what kind of a building will be against maximum and minimum external factors in the extraction of an average of three plus one flats in buildings to be built in a masonry type. In the treated part, an example of a two-storey building is given in this way.

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