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**THE EFFECT OF FLOORING SYSTEMS ON
THE COST OF EDUCATIONAL BUILDINGS**

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YÜKSEK LİSANS TEZİ**

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İmza

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Tarih:

ÖZET

YÜKSEK LİSANS TEZİ

THE EFFECT OF FLOORING SYSTEMS ON THE COST OF EDUCATIONAL BUILDINGS

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Majör sismik bölgede inşa edilen yapılar, insanların yaşamını deprem durumunda koruyabilmeli veya en azından insanların yaşamını yitirmesine yol açmayan deformasyonlara maruz kalmalıdır.

Taşıyıcı sistem tasarlanırken, deprem meydana geldiğinde yapıya yüklenecek yüklerin belirlenmesi ve bu deprem yüklerine göre doğru tasarım yapılması gerekmektedir. Aynı zamanda ekonomik olmak da göz önünde bulundurulmalıdır. Döşeme sistemlerinin seçilme tipinin deprem davranışı, taşıyıcı sistem seçimi ve maliyeti üzerinde etkisi olmaktadır. Aynı zamanda, herhangi bir yapının inşasında ve tasarımında maliyet ve ekonomi çok önemli faktörlerdir. Bu çalışmanın amacı, yapısal döşeme sistemlerinin inşaat maliyetine etkisini araştırmaktır. Bu nedenle, bu çalışmada, kirişli döşeme sistemi, kirişsiz döşeme sistemi ve dişli döşeme sistemi farklı döşeme sistemleri olarak seçilmiş, daha sonra tüm analiz ve yapısal tasarım hesaplamaları ve metraj hesabı dört farklı okul için farklı açıklıklar ve farklı mimari tasarımlar (8, 16, 24 ve 32 sınıf okul binaları) dikkate alınarak yapılmıştır. Bu okulların analizinde, Türk Deprem Yönetmeliği 2007'de belirtilen dört tip sismik bölge (1., 2., 3. ve 4. sismik bölgeler) ve dört tür zemin sınıfı (Z1, Z2, Z3 ve Z4) incelenmiştir. Bu çalışmanın amacı, yapılarda kullanılan beton, kalıp ve demir miktarlarını bilmek ve ekonomik etkilerini anlayabilmektir.

Bu çalışma 5 bölüm halinde hazırlanmıştır. Giriş ve amaç ilk bölümde açıklanmıştır. İkinci bölüm, bu çalışmaya referans olarak alınan makaleler ve tezler için literatür taramasıdır (kaynak araştırması). Üçüncü bölüm, bu çalışmada kullanılan materyaller ve analiz yöntemidir. Dördüncü bölüm, her model için yapısal malzemenin sonuçlarını ve miktarlarını göstermekte ve kalıp, beton ve demir olmak üzere her model için metraj hesaplarını içermektedir. Beşinci bölüm, bu çalışmanın sonucu ve önerileridir.

Anahtar Kelimeler: Kirişli döşeme sistemi, Kirişsiz döşeme sistemi, dişli döşeme sistemi, Sismik, Yapı.

ABSTRACT

MS THESIS

THE EFFECT OF FLOORING SYSTEMS ON THE COST OF EDUCATIONAL BUILDING

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The structures that construct in the major seismic zone, should be able to protect people life in earthquake situation or at least to suffer deformations that do not lead to loss of people life.

While designing the structural bearing system, it is necessary to determine the loads that will be loaded on the structure when earthquakes occur and make accurate design according to these earthquake loads. At the same time, being economic should be taken to consideration. Obviously, the selecting type of flooring systems will have effects on earthquake behavior, carrier system selection, and cost. At the same time, cost and economy are very important factors in constructing and designing any structure. The aim of this study is to investigate the effect of the structural flooring systems on the construction cost. So, in this study, three types of flooring systems are selected which are solid flooring system with beams, flat flooring system without any beams or drop panel, and ribbed flooring system, then all calculations of analysis and structural design, and the bill of quantity for four different schools having different spans and different architecture designs (8, 16, 24, and 32 classroom's schools buildings) are made. Structural designs for these schools are analyzed in four types of seismic zones (1st, 2nd, 3rd, and 4th seismic zones) and four types of soil (Z1, Z2, Z3, and Z4) that are mentioned in Turkish Earthquake Code 2007. The objective of this study is to know the quantities of concrete, formwork, and steel that are used in structures, and to know their economic impact.

This study has been prepared from 5 chapters. The introduction and the purpose are explained in the first chapter. The second chapter is the literature review for articles and thesis that are taken as a references for this study. The third chapter is the materials and the method of analysis that is used in this study. The fourth chapter show the results and quantities of structural material for every model and make a bill of quantity for every model for formwork, concrete, and steel. The fifth chapter is the conclusion and recommendations of this study.

Keywords: Solid flooring system, Flat flooring system, Ribbed flooring system, Seismic, Structure.

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1. INTRODUCTION

Structure is a system composed of connected and balanced structural elements like slabs, beams, grids, columns, foundations, and other elements that protect the building from collapse and transfer the load that is applied on it to the soil.

Slab is one of the structural elements which is a flexural element of uniform thickness. The slab is a horizontal element that is formed to provide flat surfaces in building floors, roofs, bridges, and other types of structures. Slabs may be supported by walls, by reinforced concrete beams that cast monolithically with the slab, by structural steel beams, by columns, or by the ground. The concrete slab is cast on temporary formwork or centering of lumber, plywood, or metal panels that are removed when the concrete has reached sufficient strength to support its own weight and construction loads.

One of the most important examples for the early reinforced concrete slab was Soo Line terminal in Chicago which was constructed in 1913. This terminal was tested in some terms of a load of ten railway cars at 200.8 Kips (893,158N). One panel of the Schwin Bicycle Factory in Chicago was also loaded to 450 psf (21,546 N/m²) for the year. However, the rational analysis of slabs has fallen behind the practice of designing and construction. When the first rational analysis was found by Nichols in 1914, more than 1000 flat slab buildings had already been built.

There are three important types of slabs or flooring systems:

- Solid flooring system.
- Flat flooring system.
- Ribbed flooring system.

In general, slab is classified to two main types:

- 1- One-way slab.
- 2- Two-way slab.

In general, the loads, span and cost are determine the suitable type of flooring system. The one-way slab is one of the simplest forms of a solid slab. It is considered economical for small span when the ratio between long directions to the short direction exceed 2. Due to this point, the one-way slab is low in efficiency and weight.

Sometimes, the reduction of the weight can be applied by using some forms of elements in order to create hollow voids in the slab.

On the other hand, the two-way slab is usually used for heavy loading and large spans (when the ratio of long direction to the short direction does not exceed 2). The reinforcement in the two-way slab should be designed to enable the slab to transfer loads in both directions. The ratio of long to short direction of the floor panel determines the load proportion that is taken by each set of reinforcement.

There are two types of Two-way slab:

- Two-way slab with Edge support (Edge supports may be bearing walls or monolithic beams).
- Two-way slab without beams (It could be called flat plate system or the flat slab. Only the column supports and slab can be of this type).

The ribbed slab is working and transfer loads in one direction, while a waffle slab gives added strength in both directions. This is possible only in monolithically cast concrete which is the two-way grid of beams. With comparison to the solid slab, the span limits in ribbed slabs are considerably longer.

The choice of type of flooring systems for a particular floor depends on many factors. The economy of construction is a very important factor. Design loads, required spans, serviceability requirements, and strength requirements are also important factors.

In any structural system, there are two main steps, structural analysis, and structural design. Structural analysis is the force acting on different elements of the structure that can be determined through structural analysis. Moments, torsion and shear forces are considered as the most common forces which are calculated. Complicated equations may be used in this calculation works and this requires to use computer software as well as trained and experienced engineers.

However, the basic understanding of this idea of the design and structural analysis is importantly required. So to ensure that the design is suitable and the calculation is also correct, a software program should be used. The result produced by the computer programs will be correct, but the error might be in the input information.

There are many types of software that can be used for calculating analysis and design, like ETABS, SAFE, PROKON, and STA4CAD, etc. The STA4CAD program is selected because of its efficiency in producing accurate values, easy to use, and also

this program can calculate the quantities of concrete, steel, and form and make a bill of quantity for the projects.

As mentioned before, the objective of this study is to compare the solid slab, flat slab, and ribbed slab based on the quantity of concrete, formwork, and steel reinforcement to be consumed during construction. Also to compare between these slab types in cost or economic evaluation under seismic and wind loads on the four types of the seismic zone in Turkey and also under different types of soil that are mentioned in Turkish standard (TS 500) and Turkish earthquake code 2007.



2. LITERATURE REVIEW

In the study that was made by Sabah, M.G and Toropov, V.V. 2005, cost optimization of reinforced concrete flat slab buildings according to the British Code of Practice (BS8110) is presented. The objective function is the total cost of the building including the cost of floors, columns and foundations. The cost of each structural element covers that of material and labor for reinforcement, concrete and formwork. The structure is modelled and analyzed using the equivalent frame method. The optimization process is handled in three different levels. In the first level, the optimum column layout is achieved by an exhaustive search. In the second level, using a hybrid optimization algorithm, the optimum dimensions of columns and slab thickness for each column layout are found. In this hybrid algorithm, a genetic algorithm is used for a global search, followed by a discretized form of the Hook and Jeeves method. In the third level, an exhaustive search is employed to determine the optimum number and size of reinforcing bars of reinforced concrete members. Cost optimization for three reinforced concrete flat slab buildings is illustrated and the results of the optimum and conventional design procedures are compared.

In the study that was made by Akgün H. 2007, three different flooring systems of a multi-story reinforced concrete building were selected as an example. In this study, 10 - 15 - 20 and 25 stories building was modeled and analyzed by using three types of flooring systems in every building. These flooring systems were solid flooring system, flat flooring system, and ribbed flooring system. Spectral values, base shear force values, 1st natural periods and S_a value was applied in x and y directions on all buildings in 4 different soil types and 4 different earthquake regions. The results of the study showed that the tests carried out on the three different flooring systems were very important in terms of the horizontal load stiffness of the frame system in the case of the ribbed flooring system and the solid flooring system that the bearing system elements such as beams, columns and shear walls were introduced. In addition, since the structural system with the least rigidity was the flat flooring system when the flooring systems of the building are changed, the maximum period of the structure exposed to the effects of the horizontal loads occurs in the flat flooring system.

In the study that was made by T. Öztürk. and Z. Öztürk. (2008) investigated the effects of slab types on the behavior of load carrying systems. In this study, models are analyzed on multi-story reinforced concrete buildings under seismic loads according to the rules and regulations of the current Turkish Earthquake Code (TEC). Slab openings in floor systems may cause irregularities in the horizontal plane according to the earthquake code. Analysis of the case in which the slab openings are formed very close to the vertical load carrying elements is also included in this study. The results obtained from all the analyses carried out and all the works done in this study are explained and summarized with diagrams.

In the study that was carried out by Adem, T. 2011, investigated the effect of structural behaviors for similar structural systems on the quantities of formwork, concrete, and steel and the effect to the constructions cost. In this study, two types of buildings and two types of flooring systems had been used. The buildings that were used were residential and sport building, also the flooring systems that were used in this study were solid flooring system and flat flooring system. For this purpose two different systems have been taken into consideration, namely vertical framing system consisting of columns only and vertical framing system used concrete shear walls with columns.

The result showed that flat flooring system are more costly in using formwork, concrete, and steel than solid flooring system. When all the systems are examined in terms of weight, it is seen that the structures with flat flooring systems are higher in both framed and shear walls- framed systems than solid flooring systems. This means that flat flooring system need more reinforcement and concrete from the other flooring system.

In a study carried out by Uzun D. 2014 was intended to investigate the effect of the selection of solid slabs or flat slabs on the building cost devoted to the intended use. Thus, the cost of the buildings are compared having the same structural configuration and period. In this study, the building or structure consist of 33-reinforcement concrete story with seismic resisting system was analyzed and designed according to Earthquake Regulations 2007 and TS500 under vertical and horizontal loads. The effect on the behavior of the bearing system is taken into account when the elevated building has four different flooring systems. Flooring systems that were used in this study was solid flooring system, ribbed flooring system in one direction, flat flooring system, flat

flooring system with edge beams. For this purpose, the three-dimensional model of the building support system was created using ETABS software, and modeling floors were included.

The most important parameters affecting the building behavior are free vibration periods varied depending on the building weight and the stiffness of the carrier system. The use of a ribbed flooring system has increased the weight of structure compared to other flooring systems, and the structural weight is at least calculated in the case of a flat flooring system. The first free vibration period was occurred in the case of the flat flooring system, as the building weight decreased and the bearing system rigidity decreased. The model with the lowest period was the solid flooring system. This flooring system, which has all the horizontal and vertical structural system elements (shear walls, columns, beams, and flooring) with a symmetrical structure plan, is the highest rigidity due to the formation of regular frames and due to the rigid frame system due to the beam dimensions.

The ribbed flooring system takes the greatest base shear force because it has the most weight. The solid flooring system and flat flooring system with edge beams give very close base-shear values, it has been determined that at the solid flooring system has the lowest base shear force in both directions between all flooring models, even though it has the highest values per period.

Maximum floor displacements have emerged which was flat flooring system and the second most displaced slab system was flat flooring system with edge beams. The most rigid and least displaced for both earthquake directions was the solid flooring system.

In the study that was made by Yonca. A. 2014, presented experimental investigation for strengthening RC slabs under impact loads using shear reinforcement. Slabs were strengthened against punching shear with two methods: using shear studs as shear reinforcement and using steel fiber reinforced concrete (SFRC) instead of plain concrete. Eight RC slabs with dimensions of 2150x2150x150 mm were tested. Four of the specimens, two identical pairs, were cast with shear studs around the point of impact. Remaining four specimens, again two identical pairs, were cast with 1% steel fibers. Pairs in each group contained two different levels of longitudinal reinforcement. For each pair, one specimen was tested under static loading, whereas its identical twin was tested under impact loads. Specimens were tested with a test setup that provides simply supported conditions. Support loads, displacements, accelerations, and strains on

bars were measured during the tests. The study revealed that using shear studs and SFRC prevents brittle punching shear failure for both static and impact loading. Specimens with steel fibers reached the highest load carrying capacity for static test while specimens with shear reinforcement carried a smaller load for large deformations. Specimens with SFRC displayed a close to static behavior under impact loading, influenced only slightly by inertial forces due to impact. Specimens with shear studs were largely influenced by inertial forces and scabbing occurred at some areas. Specimens with steel fibers endured more impacts compared to control specimens and specimens with shear studs due to their higher energy dissipating capabilities.

In the study that was made by Makode, R.K., Akhtar, S. and Batham, G., 2014, presented the rapid growth of the urban population and the consequent pressure on limited space has considerably influenced multistoried building construction. With increase in demand for space, construction of multistoried buildings is becoming a necessary part of our living style. These multistoried buildings can be constructed using various structural systems. Two main groups according to the arrangement of slabs, beams or girders, and columns are Framed Structure and flat slab structure. Framed structures are the structure having the combination of beams, columns and slabs to resist the lateral and gravity load. These structures are usually used to overcome the large moments developing due to the applied loading. The flat slab buildings in which slab is directly rested on columns, have been adopted in many buildings constructed recently due to the advantage of reduced floor to floor heights to meet the economical and architectural demands.

In this study that carried out by Fatmana. Y. 2015, presented the structures modeled with three different flooring systems as 6-storey with only frame resisting system and 12-story with frame and concrete shear walls resisting system. All models were put under horizontal and vertical loads and analyzed by ETABS program. The flooring systems that were used in this models were solid flooring system, flat flooring system, and ribbed flooring system. Concrete designs were made by checking the conformity of the obtained results with the regulations and periods of structures, weights, base shear forces and reinforced concrete, then the design data were compared in the direction of the obtained results. In 6-story constructions, when the period values were examined, the period of the ribbed flooring system was 18% higher than the period of the solid

flooring system, whereas it was 55% higher than that of the flat flooring system. In the case of 12-storey constructions, the difference between the period of construction with ribbed flooring system and the period of flat flooring system was 1%, while the period difference between both ribbed and flat flooring system with solid flooring system was 8%. Compared to the building weights and the loads on it, the 6-storey and the 12-storey constructions, solid flooring structures were the heaviest building. Followed by the ribbed flooring structures. At least the weight of the structure was solid flooring structures. In the analysis, quantities of concrete and steel were calculated. According to the concrete metric, the concrete consumption was mostly in flat flooring structures. The lowest expenditure was on ribbed flooring structures. According to the steel, the minimum amount of steel consumption in the solid flooring structures, and the maximum amount of steel was in the ribbed flooring structures. According to the cost comparisons by considering only the consumption amounts of concrete and steel, it is seen that the structure modeled by the solid flooring systems was more economical for the other structures in 6 and 12 storey architectural plan, whereas the structure modeled by the ribbed flooring system was the most expensive system.

The aim of the work done by Koçuk F. (2017) is to investigate the problems that occurred in the modeling and analysis phase of historical agglomeration and to examine the effect of the flooring systems on the behavior of the building by modeling its real behavior as much as possible. The scope of this thesis, the A block building of the Old State Archives (Eski Devlet Arşivleri A blok binası) located in the Beyazıt settlement in Istanbul University was selected as the sample structure and the numerical solution methods of the different floor types were applied by considering the effect of the different floor types on the bearing walls. Damage patterns in historical buildings and the stresses that caused them have been investigated.

In the study that was made by Alraie, A., & Barik, M. 2017, investigated the effect of continuity on reduction factors of bending moment and shear forces in grid slab. Grid slab is a type of floor system consisting of beams running in both directions monolithic with the slab. It is usually employed for architectural reasons in large halls such as auditoriums, restaurants, theatres and other halls where column-free space is often the main requirement. The literature is silent on dealing with such type of slabs. Some international codes like the Syrian code focus on this type of slab and provide a table of

reduction factors, but which is for simply supported slab only. These values are no longer valid for the case where continuity exists. Hence this paper attempts to study the effect of continuity on the reduction factors of bending moments and shear forces of grid beams in grid-slab and obtain the reduction factors for different cases of continuity. For validation of the results, SAP 2000 software is used to obtain those values for different cases of continuous slabs. For this, a number of models having different sizes of slabs are considered. A number of analyses are performed taking all probable cases into account for three different percentages of continuity: one-third, two-third and full-length. The investigation of the effect of continuity is carried out by considering a slab having five beams and the reduction factors of bending moments and shear forces are presented in tabular forms. The study shows that it is beneficial when continuity is taken into account ultimately resulting in an economical design.

In the study that was made by Shu, J., Belletti, B., Muttoni, A., Scolari, M., & Plos, M. 2017 investigated the structural behavior of RC slabs subjected to concentrated loads leading to punching shear failure using shell and continuum nonlinear finite element analysis (NLFEA). Shear force distributions are studied for four types of slabs with different geometry of support, geometry of slab and layout of reinforcement. All factors investigated have been proven to influence the shear force distributions along the control perimeter around the support. Significant shear force redistributions due to cracking and reinforcement yielding have been observed using NLFEA. Reduced control perimeters to be used for simplified approaches accounting for calculated shear force distributions are calculated using both NLFE approaches.

3. MATERIALS AND METHOD

Floor or slab is a horizontal reinforced concrete element that transfer the loads that apply over it to the supporting elements such as column, beams or walls. It is assumed that these loads are spread as a uniformly distributed load on the floor. In the heavy load cases, different analysis methods must be used to determine the cross-sectional effects. Transmission of lateral loads such as earthquake and wind load to the vertical structural elements is also carried out through the slabs. Transfers of loads through the slab are occurred according to rigid diaphragm acceptance [4]. The acceptance of the rigid diaphragm assumes that the floor acts as a rigid mass without deformation in its plane under lateral loads [5]. Thicknesses are determined depending on the spans between supports, type of supports, and amount of dead load and live load that applied over it. The main function of slab is to transfer load to the supports, it also works as sound, heat and humidity insulation, and fire resistance.

3.1. Materials

In the world, there are many types of slabs or floors that work as horizontal structural members. Today slabs or flooring systems can be classified according to the method that apply to transfer load to the supports and also according to the support types and spans between supports.

In this study, the flooring systems types that are used in building systems are classified in three main types:

- 1- Solid flooring system (slab with beams between supports)
- 2- Flat flooring system (slab without any interior or exterior beams between supports)
- 3- Ribbed flooring system.

Solid slab, is the structural flooring system that transfer loads to the supports, its supports should be beams. Loads in solid slab is transferred as one or two direction according to supports and spans length. The thickness of this type of slab is determined according to the length of spans between supports, and also according to the amount of dead and live load that is applied over it.

Flat slab, is the structural flooring system transfers loads from slab to the columns directly without using beams.

Ribbed slab, is a structural flooring system that transfers loads to the small beams, which are called "ribs" which are close to each other and whose directions are parallel to each other. Those ribs transfer loads to normal beams and to the supports.

3.1.1. Solid flooring system

It's one of the structural flooring systems. In this system, slab is set on the beams at least in one or two edges. This type of slab is preferred in residential buildings. The supports in this type of slabs should be beams. Beams may be in all sides of slab or may be in one or two side and other sides will be free.

The beams that take loads from slabs can be designed to have high ductility and rigidity according to the loading situation. For this reason, this type of floor is constructed and preferred in earthquake regions because of the rigid diaphragm effect that occurs in the structure.

When the applied load on the slab is great and the span between supports is large, the thickness of slab increase and this decreases the economy. In addition, when the slab thickness increases, the slab in analysis, will be divided into smaller areas. However, if the slab thickness is low, the dimensions of the carrier elements can also be economically designed.

In this system, slab is divided into two type according to the ratio of long direction to the short direction of clear span:

- One way direction.
- Two way direction.

In one way direction type of slab, slab is supported to beams and the ratio of the long span length to the short span length should exceed 2 (figure 3.1). In this system, loads are only transferred in the short direction. So in this case, the analysis calculation and main reinforcement or tension bars should be calculated and placed

only in short direction side. On the other hand, in the long side, it is not important to calculate tension or moment or make analysis calculation but should distribute some bars for shrinkage and temperature.

In the type of solid slab that supported to beams, if the ratio of long span length to the short span length should not exceed 2, this type is called two way slab (figure 3.1). In this system, loads are transferred in both direction, long and short direction. So in this case, the analysis calculations and main reinforcement or tension bars should be calculated and placed in long and short direction side. Due to biaxial load transfers, it is possible to carry the same load with more slender sections than those working in one direction. Under uniformly distributed loads, the load distribution ratios of these slab systems in two directions can be applied, also in these directions a continuous beam analysis can be applied for both directions by accepting the conditions.

The advantage and disadvantage of solid slab with beam flooring system:

- Most suitable flooring system in earthquake cases.
- The cost of the formwork is high even though the amount of material that used of the slabs is low.
- For cantilever slabs, solid slab system is very suitable for this case.
- Solid slab with beams system is not suitable in structures that have long spans between supports comparing with other flooring systems.
- Beams decrease the floor height and negatively affect the usage.
- In situations such as changing the location of the walls depending on the changes in the use of the structure, solid slab with beams flooring system is not very suitable. If the wall loads is not considered in slab analysis calculations and after that a wall construct in the mid-region of the slab, this may cause deformation and damage to the slab.

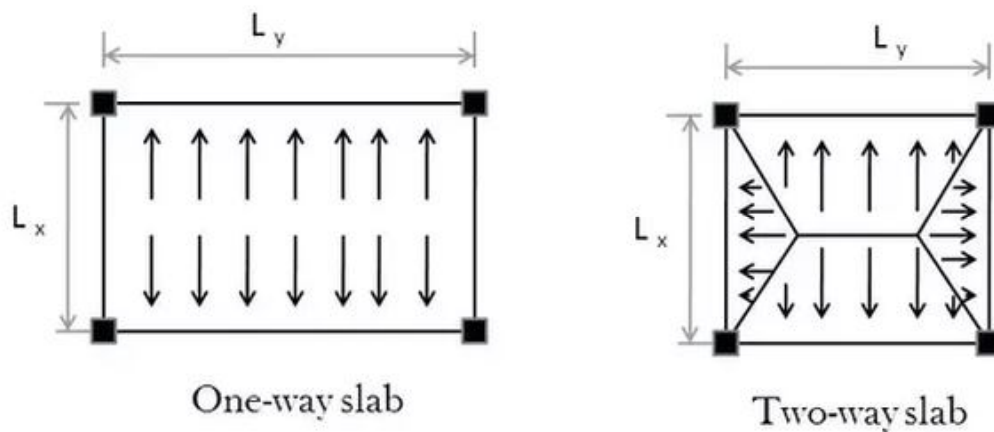


Figure 3.1. One way slab system

3.1.2. Flat flooring system

It is a plate without beams that sits directly on the columns. The loads in this types of slabs are transferred directly to columns without beams. In flat slab, slab strips are formed for transporting vertical and horizontal loads of the building and transferring them to the supporting columns and shear walls (if found) because there are no beams in the horizontal plane (Figure3.2). Slab strips are formed as required by the load distribution and balance at the floor. Therefore, it is very important that the axes system on which the columns are placed is on proper axes. In flat slabs, the thickness of the slab, reinforcement arrangement and distribution must be carefully considered to ensure a safe diaphragm effect against lateral loads.

In flat flooring system, if there are no hanging beams under slabs, slabs will be low formwork and low cost and flat view is obtained. However, it cannot exhibit a good structural behavior. One of the negative effects of this type of flooring system is the punching effect at the beginning of the columns due to the direct seating of the slab on the column (Fig. 3.3). This punching effect is also effective when the floor thicknesses are determined.



Figure 3.2. Flat Flooring System

In flat flooring system, in the very heavy load structures like Industrial structures or bridge parking, punching shear in connection area between columns and slabs will be very dangerous. For this problem, slab can be made with column head to prevent structure from punching shear failure as shown in (Figure 3.5). Thus, the flooring thickness is locally increased in these affected areas. In addition, for solving punching shear failure in structure, drop panel in connection area between columns and slab can be made (figure 3.4). The dimension, thickness and other details of column heads or drop panel can be taken due to standards. Special reinforcement or steel bars can also be added to increase the punching strength in cases where the column heads or drop panels are not available. In this way, the strength to resist the punching shear effect is obtained. Hidden beams are suitable for the work place, where the loads are light and the spans are not too large. However, the use of column heads can negatively affect architecture and economics.

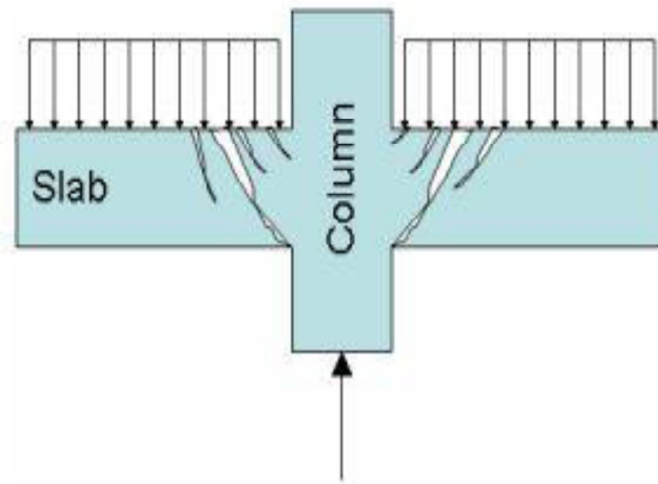


Figure 3.3. Punching Shear Failure



Figure 3.4. Drop Panel in Flat Slab



Figure 3.5. Column head in flat slab

According to Turkish Earthquake Code 2007, structural ductility is classified into high ductility level and normal ductility level. In the seismic zones in Turkey, if the columns in any structure are not computable with the conditions of high ductility level, it will be considered as normal ductility level due to Turkish Earthquake Code 2007. In the case of non-reinforced concrete shear wall in the normal ductility level, only the third and fourth degree earthquake zones are allowed and the total height of the building should not be more than 13 m, but for the first and second earthquake degree zones, it is necessary to use reinforced concrete shear walls to limit the damages that may occur in normal flat flooring systems. For this reason, it is not suitable to use flat flooring system type without reinforcement shear walls in areas that are located in the earthquake zone Turkey (especially in the first or second zones).

The advantage and disadvantage of flat slab without beam flooring system

- The punching effect in flat slab systems, creates difficulties in applying these slabs in earthquake zones.
- Quick and easier implementation, because the slab is flat and don't contain any beams.
- High thickness in flat slab and the amount of reinforcement will be more than some other slabs like solid slab.
- Formwork or mold is economical more than other type of flooring systems.
- Flat slab is one of the flooring systems that suitable for long spans structures.
- It is a suitable system for the changing walls locations due to the changes in usage of the building.
- The flat flooring system is sufficiently rigid because the slab thickness is high.
- Very difficult to design long and heavy cantilever in flat flooring systems.

3.1.3. Ribbed flooring system

Ribbed slab is a flooring system which is formed by suitable ribs parallel to each other on the main beams and by making a very thin cover on it. Free openings of frequently formed ribs in one or two directions are regulated between 400 mm and 700 mm (Figure 3.6). Loads are transferred to ribs and after that these ribs transfer loads to the main beams then to the columns or shear walls.

This flooring system is a much preferred flooring system in cases where there is a large spans, or where singular and strip loads affect the flooring, because it is made up of frequently arranged ribs and main beams that sit on these ribs.

Since the load is carried by the ribs and transferred to the supports, the thickness of the flooring between the ribs is less than the thickness of the normal flooring.

The ribs in the slab are usually made in the long edge direction of the slab, so that the main beams are not too hard. When the ribs are placed in a long direction, the ribs are forced because the ribs span is large. All of the floor loads transfer to the main beams where the ribs sit, and these main beams do not strain very much.

If the ribs are placed in the short direction, the span will be small and the ribs will not be too hard. However, all of the floor load will be transferred to the large main beams where the ribs sit, and the main beams will be very hard.



Figure 3.6. Ribbed flooring system in one way direction

In this flooring system, ribs are usually arranged in one direction. It can be arranged in two directions where the floor spans is too large and / or the loads are too heavy (Figure 3.7).

Between the ribs, the bottom of the slab is left empty or filled with a light filling material like hollow block or polystyrene (foam). This type of flooring is called ribbed flooring system. Standard sized light blocks, specially produced for this purpose, are used as filling material, such as hollow concrete, hollowed clay, aerated concrete, or foam. Hollow blocks have no carrier characteristics. It is only considered as a light load, it is assumed to be unavailable in static and reinforced concrete calculations. Figure (2.7)

Due to the Turkish Earthquake Code 2007, if the structures that have ribbed flooring system or waffle flooring system are not compatible with high ductility level conditions, it will be considered as normal systems of ductility level. Normal systems with ductility levels are not allowed to be constructed in the first and second degree earthquake zones. In this case, it is necessary to use reinforced concrete shear walls in structures to limit the damages that may occur in normal ductility level systems with ribbed slab system.

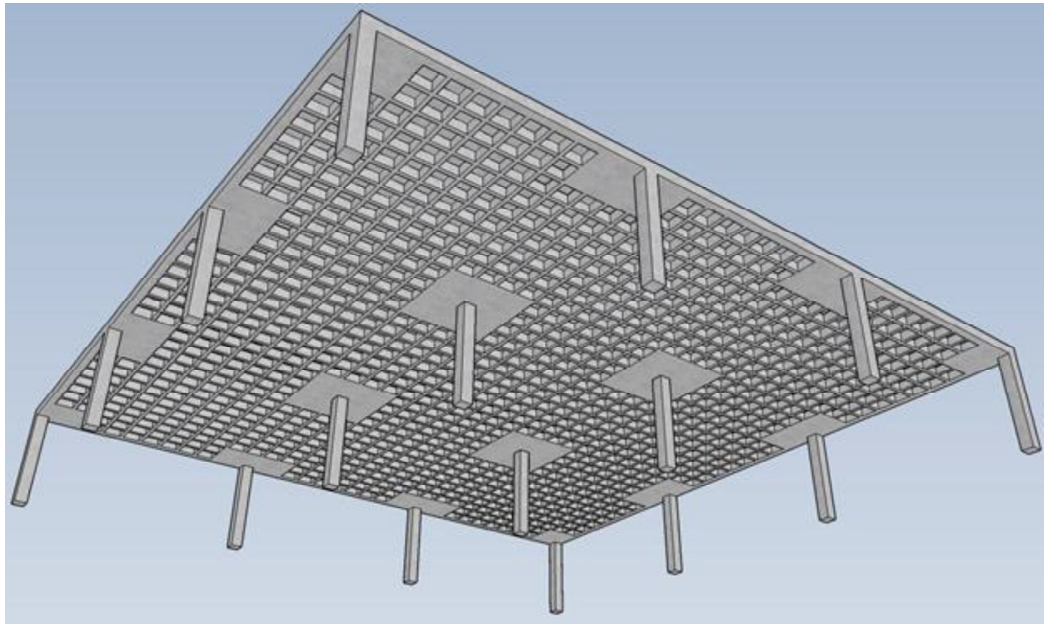


Figure 3.7. Ribbed floor system two way direction

The advantage and disadvantage of flat slab without beam flooring system

- Ribbed flooring system shows a poor performance in seismic.
- The formwork cost is low in these systems, but the amount of material like steel bars or reinforcements that are used is high.
- Ribbed slabs are the most suitable slab system for large spans between supports.
- If the load is large or there is a concentrated or point load, ribbed flooring system is more suitable than other flooring systems.
- In situations such as changing the location of the walls from time to time the ribbed slab system is quite convenient.
- In ribbed flooring systems, there are also additional expenses due to the filling material, this increasing the weight of the slab, and increasing the amount of steel that be used in the slab

3.1.4. Turkish earthquake code 2007

The basic principles of the regulations on buildings that are made in earthquake regions 2007 are the structural and non-structural elements shouldn't be damaged in low earthquake intensity, the damage to structural and non-structural elements in moderate earthquake intensity is limited and repairable, and in case of high earthquake intensity, the permanent structural damage is limited and there is no loss of life. In this section, the design criteria, solution methods and design rules in the design of the building which are mentioned in Turkish Earthquake Code 2007 are shown.

As stated, for the structures that has a seismic resisting systems, it is necessary to design a rigid, stable and durable structure that will transmit earthquake loads continuously and safely to the ground. The principles of ductility must be taken into consideration, so that a large part of these earthquake loads are consumed by ductile behavior.

Turkey earthquake regions that are held in the danger zone are determined by map-type building structures, earthquake resistant as required in analyses calculation and construction rules. The regulations that determine the importance of buildings and the soil or ground conditions are also called as earthquake regulations.

3.1.4.1. History of Turkish earthquake code

The first earthquake regulations in Turkey was set in 1939. After the earthquake that occurred in Erzincan in 1940, earthquake regulations entered in validity. In the first earthquake regulation, which was similar to the Italian earthquake regulation, the earthquake was made similar for all regions in Turkey.

The earthquake zones map were prepared in 1942. The seismic analysis in earthquake regulations was issued since 1947 and have become attached to the seismicity of the region where the structure is located.

In the earthquake regulations that were published in 1968, the modern accounting methods which are used today were mentioned. For the first time, in this regulation, limits regarding the minimum dimensions of reinforced concrete

structural elements have been introduced. The details of the ductile structure design were included in the earthquake regulations that were published in 1975. In this regulation, jointing and winding zones of reinforced concrete members, reinforcement details for ductile behavior, and recommendations on member dimensions were presented. The implementation of the details of the ductile design in the earthquake regulations that entered into validity in 1997 has now become mandatory for buildings

Many of the codes and design rules in the 2007 earthquake regulations, which are in active today, are suitable to be used together with the 1997 earthquake regulations. Although there are some differences between the two regulations, the 2007 earthquake regulations were actually based on the 1997 regulations. In the next year (2019), the new version of the Turkish earthquake code will be published, but in this study Turkish earthquake code 2007 will be applied.

3.1.4.2. Seismic zone in Turkey according to Turkish earthquake code 2007

Turkey is one of the world's active seismic zone located on the Alpine-Himalayan seismic line. Some regions are strongly shaken, and the other regions are less affected or not affected at all (non-hazardous regions). The Turkish Earthquake Code is classifies Turkey into 4 seismic regions according to seismic intensity. In figure 3.8 (a- ÇAYNAK S. 1996, b-DEMİR C. ve diğerleri 1995) prepare earthquake map according to seismic zone that mentioned in code.

Turkish Earthquake Code 2007 classify seismic zones in Turkey as following:

1. The first degree earthquake zone: acceleration value greater than 0.40 g
2. The second degree earthquake zone: acceleration value between 0.40-0.30 g
3. The third degree earthquake zone: acceleration value between 0.30-0.20 g
4. The fourth degree earthquake zone: acceleration value between 0.20-0.10 g
5. The fifth degree earthquake zone: acceleration value less than 0.10 g.

Where g: gravity ($981 \text{ cm} / \text{s}^2$)

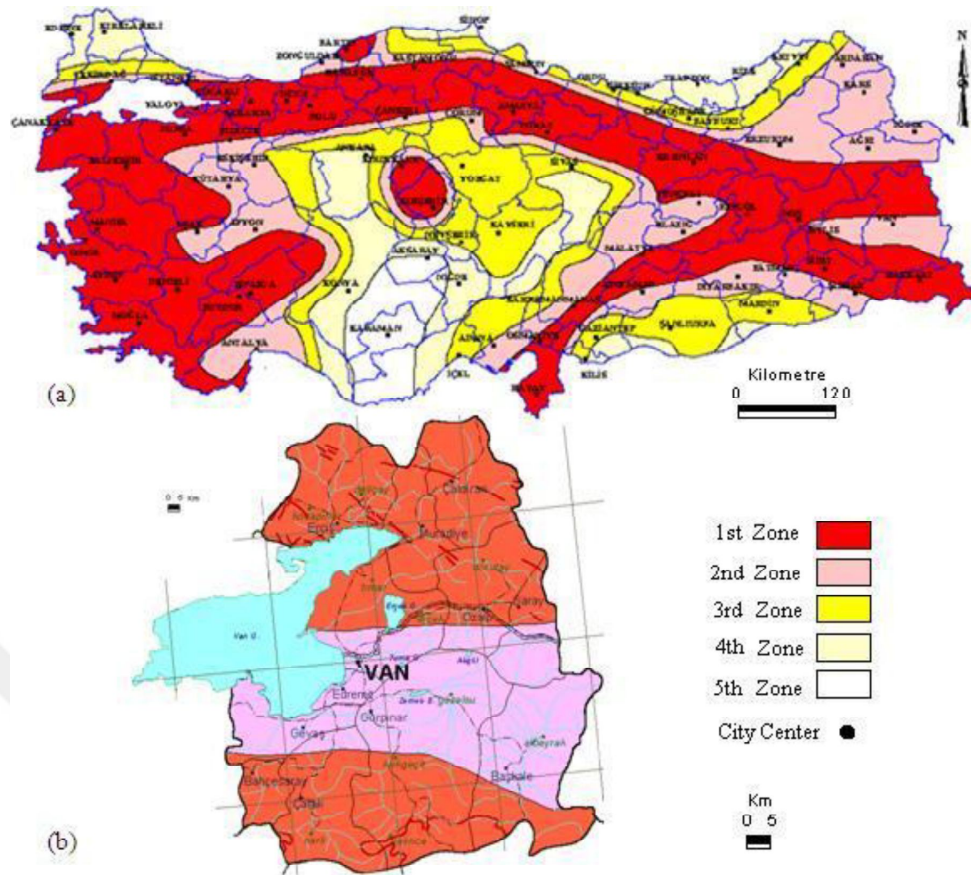


Figure 3.8. Seismic zones in Turkey due to Turkish earthquake code 2007

3.1.4.3. Acceleration spectra according to ground classes

The characteristic periods of (T_A) and (T_B) in the Turkish Earthquake Regulations are given in Table 3.1, depending on the local ground classes. Information on ground groups referred to this chart is given in earthquake regulations. The spectrum coefficients [$S(T)$] can be determined with the help of table 3.1 depending on the building period (T) and the soil characteristic periods.

Table 3.1. Periods of (T_A) and (T_B) in the Turkish earthquake regulations

Local site class	Soil group according to topmost soil layer thickness (h_1)	T_A (S)	T_B (S)
Z1	Group (A) soils Group (B) soils with $h_1 \leq 15$ m	0.10	0.30
Z2	Group (B) soils with $h_1 > 15$ m Group (C) soils with $h_1 \leq 15$ m	0.15	0.40
Z3	Group (C) soils with $15 \text{ m} < h_1 \leq 50$ m Group (D) soils with $h_1 \leq 10$ m	0.15	0.60
Z4	Group (C) soils with $h_1 > 50$ m Group (D) soils with $h_1 > 10$ m	0.20	0.90

3.2. Method

This study compares the cost between the solid flooring system with beams, flat flooring system without any beams or drop panel, and ribbed flooring system in order to show the differences in structural behaviors and structural cost. The frame structural system with shear walls and frame structural system without shear walls were chosen, because they are widely used in the constructions as carrier or seismic bearing systems.

In the study, the costs of the solid flooring system, flat flooring system, and ribbed flooring system according to four seismic zones that are mentioned in Turkey Earthquake Standards 2007 (1st, 2nd, 3rd, and 4th seismic zones) and according to four type of soil that are mentioned in Turkey Earthquake Standards 2007 (Z1, Z2, Z3, and Z4), are calculated. This mean that the ground acceleration coefficient and spectrum characteristic period are not the same for all the models.

3.2.1. General information about models

The parameters that are used for the considered structures and the accepted assumptions are given below:

- The importance coefficient of educational buildings was taken $I = 1.4$.
- All of the seismic loads were assumed to be carried by the frames and openness's shear walls. The ductility level was chosen as high ductility level in the first and second seismic zones and normal ductility level in the third and

fourth seismic zone. Here, according to Turkish Earthquake Standards, it is stated that columns and beams in flat slab flooring systems without shear walls, ribbed slab flooring systems and waffle slab flooring systems with filled or unfilled that do not provide the conditions for high ductility level, normal ductility level systems will be considered.

- In the case of non-reinforced concrete shear wall in the normal ductility level, only the third and fourth degree earthquake zones are allowed and the total height of the building not more than 13 m. In this case, it is accepted that the structures will be built in the third and fourth degree earthquake zone.
- In the used models, the height between the floors in application is taken as 3.25 m.
- Live load participation factor in all models is taken as 0.6 according to Turkish Earthquake Standards 2007 for educational building like school.
- Other information about the models that used in the study and the load information are given below:

Solid flooring system that used in all floor:

Slab thickness in school with 8 and 16 classroom: 150 mm and some slabs 180 mm.

Slab thickness in school with 24 and 32 classroom: 150 mm

Live load that applied to slab in classrooms: 3,00 kN/m²

Live load that applied to slab in corridors: 5,00 kN/m²

Dead load that applied to slab: 2.12 kN/m²

Wall load that applied to beams is gaz beton 20 cm 5,00 kN/m²

All concrete shear walls dimensions is: 30 * 240 cm

Flat flooring system that used in all floor:

Slab thickness: 250 mm

Live load that applied to slab in classrooms: 3,00 kN/m²

Live load that applied to slab in corridors: 5,00 kN/m²

Dead load that applied to slab: 2.12 kN/m²

Wall load that applied to beams is gaz beton 20 cm 5,00 kN/m²

All concrete shear walls dimensions is: 30 * 240 cm

Ribbed flooring system that used in all floor:

Slab thickness in school with 8 and 16 classroom: 320 mm

Slab thickness in school with 24 and 32 classroom:	300 mm
Live load that applied to slab in classrooms:	3,00 kN/m ²
Live load that applied to slab in corridors:	5,00 kN/m ²
Dead load that applied to slab:	2.12 kN/m ²
Wall load that applied to beams is hollow block 20 cm	5,00 kN/m ²
All concrete shear walls dimensions is:	30 * 240 cm

The models of 8 classroom's school buildings are classified as shown in table (3.2) and the other building models (16, 24, and 32 classroom's school buildings) are classified in the same manner.



Table 3.2 names of models for each type of school that used in this study

Building types	Structural flooring types	Seismic zone types	Soil types
8 classroom's school buildings	Solid flooring system	1 st seismic zone	Z1
			Z2
			Z3
			Z4
		2 nd seismic zone	Z1
			Z2
			Z3
			Z4
		3 rd seismic zone	Z1
			Z2
			Z3
			Z4
		4 th seismic zone	Z1
			Z2
			Z3
			Z4
	Flat flooring system	1 st seismic zone	Z1
			Z2
			Z3
			Z4
		2 nd seismic zone	Z1
			Z2
			Z3
			Z4
		3 rd seismic zone	Z1
			Z2
			Z3
			Z4
		4 th seismic zone	Z1
			Z2
			Z3
			Z4
	Ribbed flooring system	1 st seismic zone	Z1
			Z2
			Z3
			Z4
		2 nd seismic zone	Z1
			Z2
			Z3
			Z4
		3 rd seismic zone	Z1
			Z2
			Z3
			Z4
		4 th seismic zone	Z1
			Z2
			Z3
			Z4

The architectural plans of all schools buildings are showed in the following figures.

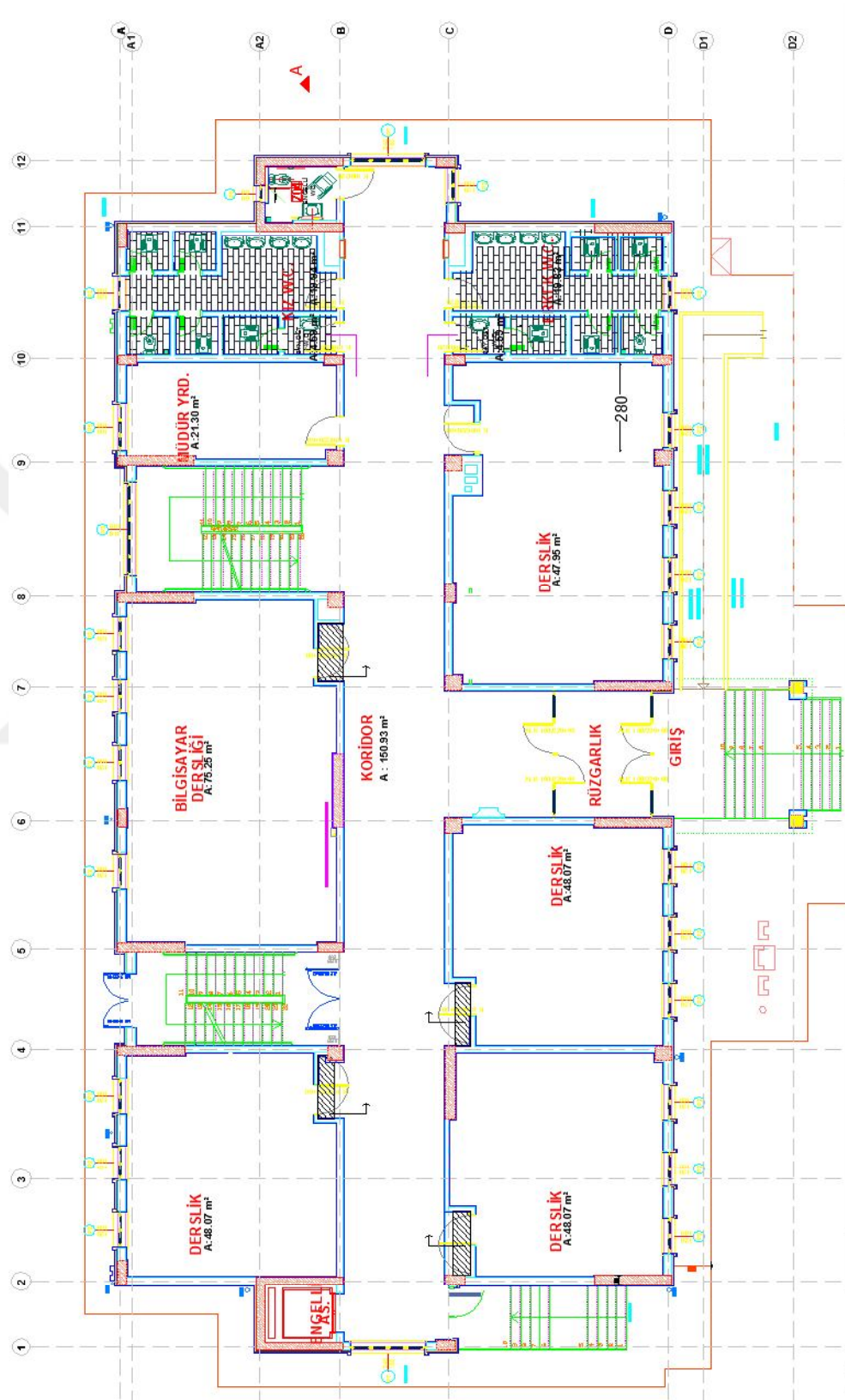


Figure 3.9. Architectural plan for 8 classroom's school building

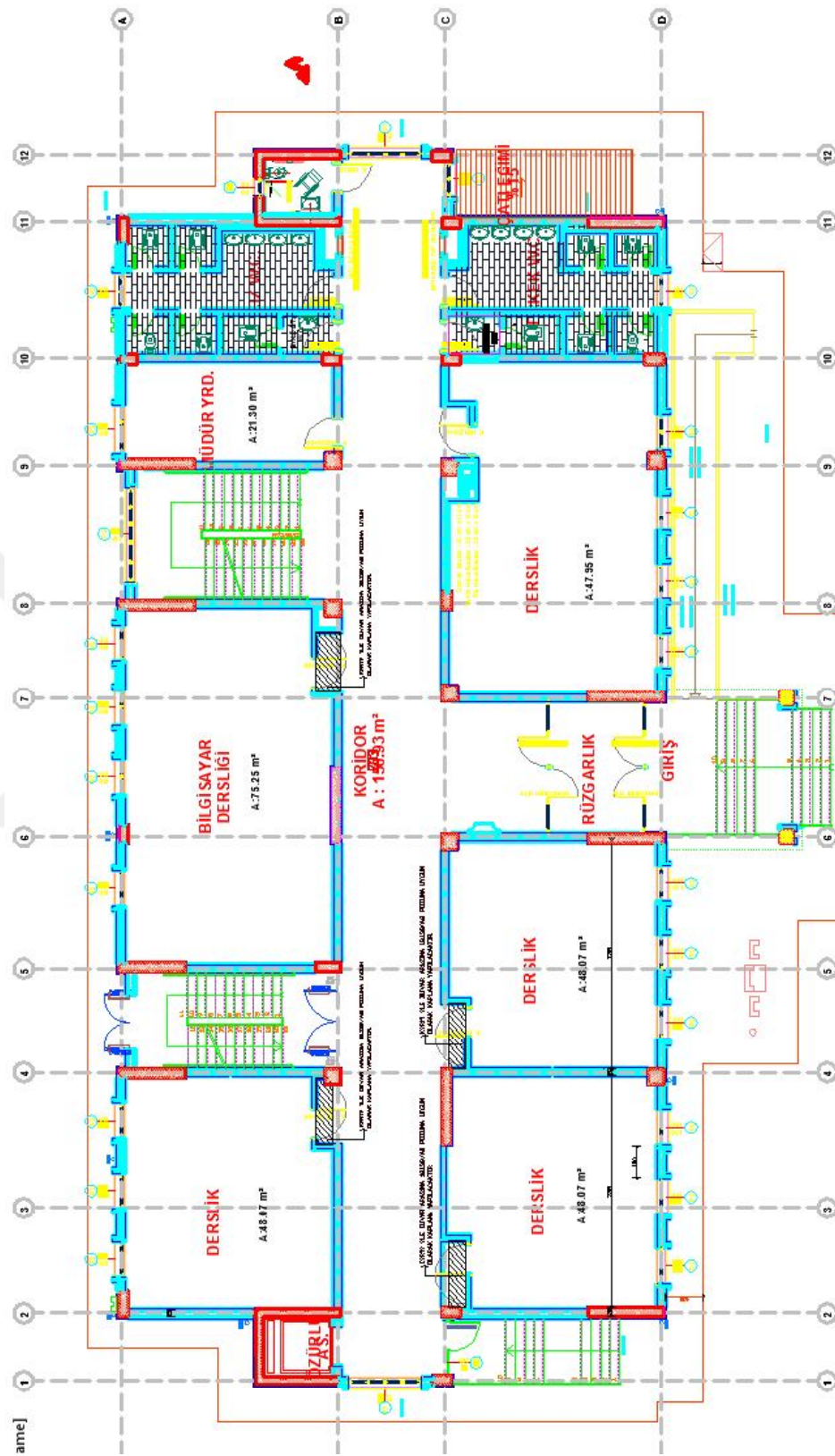


Figure 3.10. Architectural plan for 16 classroom's school

3D plan for all schools buildings are showed in the following figures

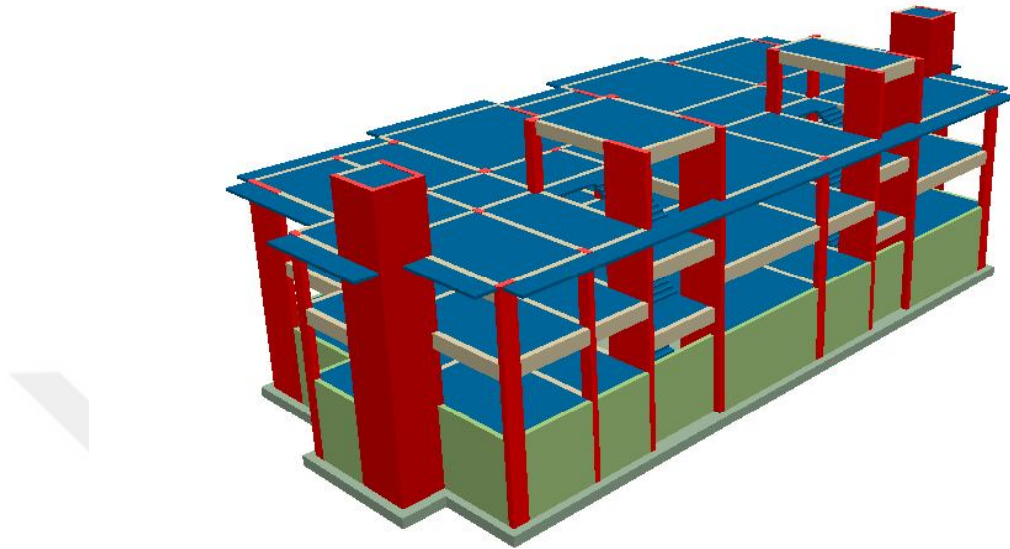


Figure 3.13. 3D plan for 8 classroom's school building

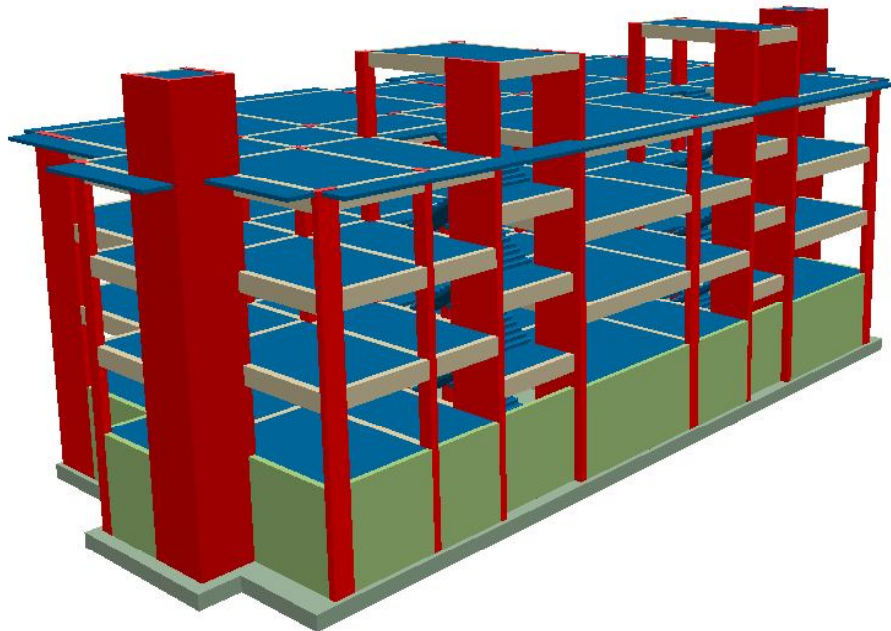


Figure 3.14. 3D plan for 16 classroom's school building

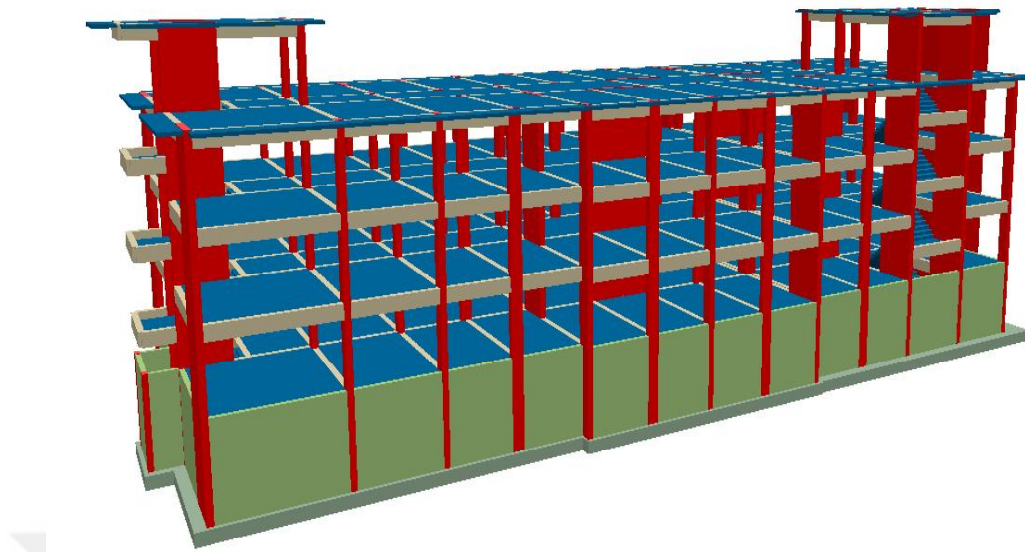


Figure 3.15. 3D plan for 24 classroom's school buildings

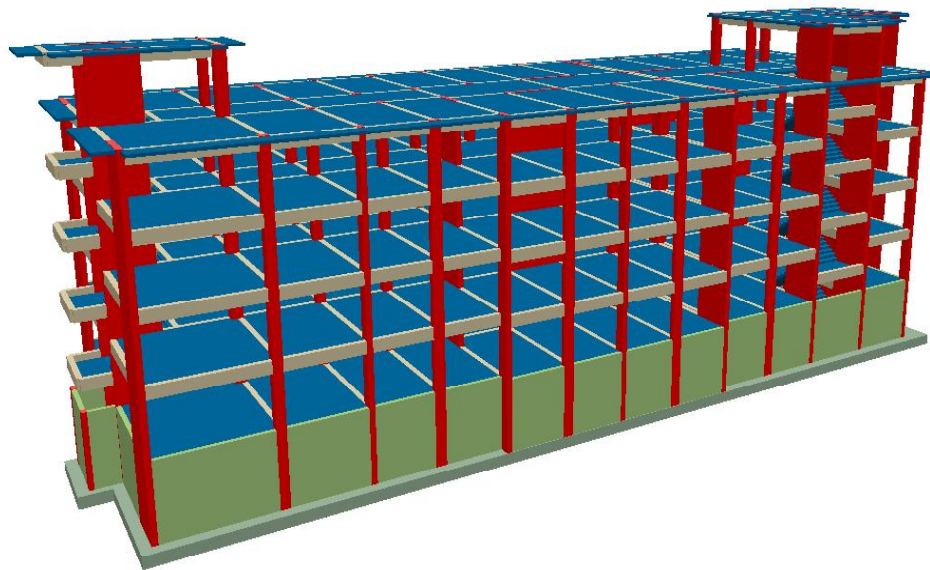


Figure 3.16. 3D plan for 32 classroom's school buildings

The structural planes for all buildings that are applied in the 1st and 2nd seismic zones are not the same in the 3rd and 4th seismic zones. For this reason, we will show the structural plans for all schools buildings in every seismic zone in the following figures.

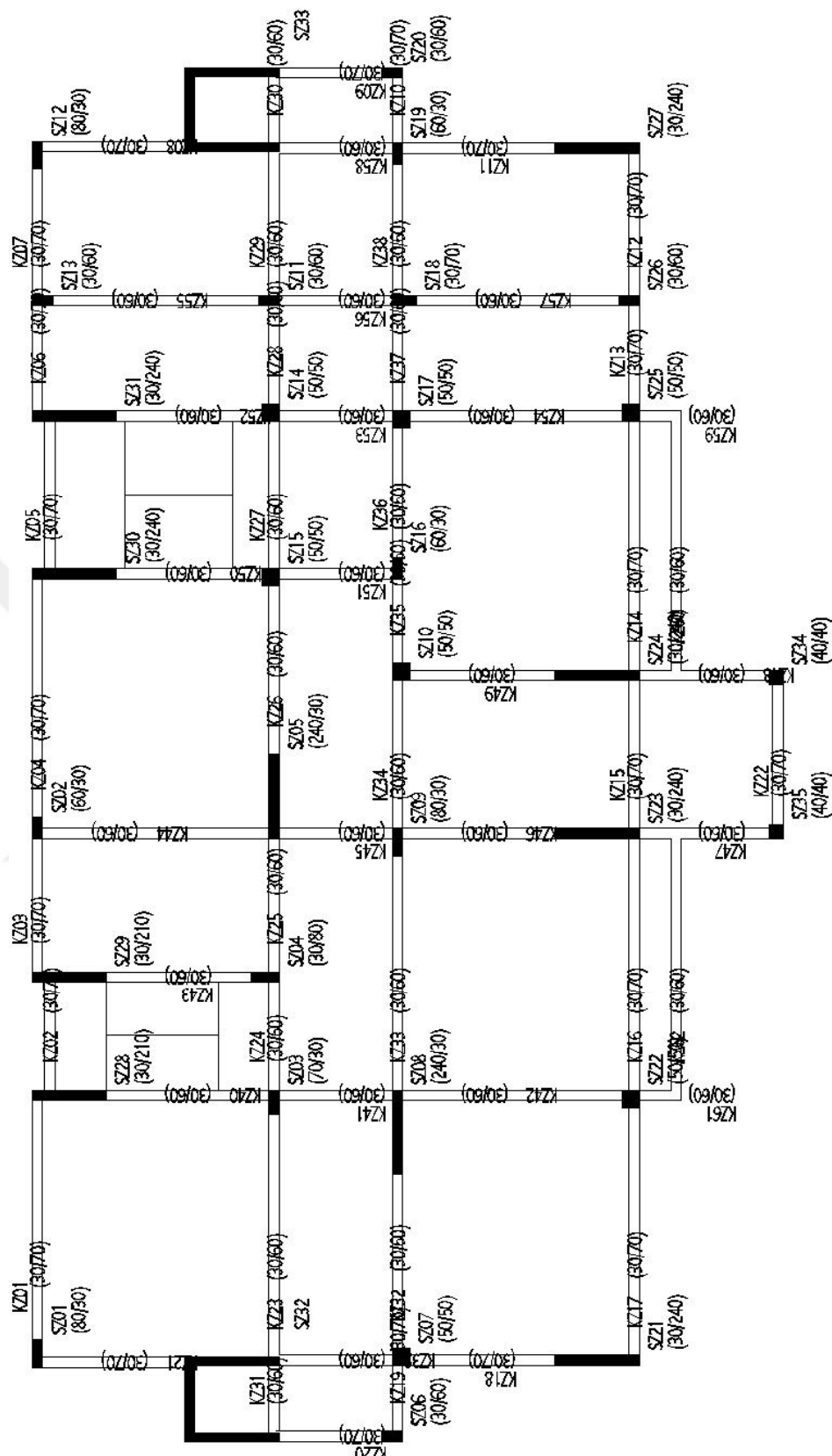


Figure 3.17. Structural plan for solid flooring system for 8 classrooms school in 1st and 2nd seismic zones

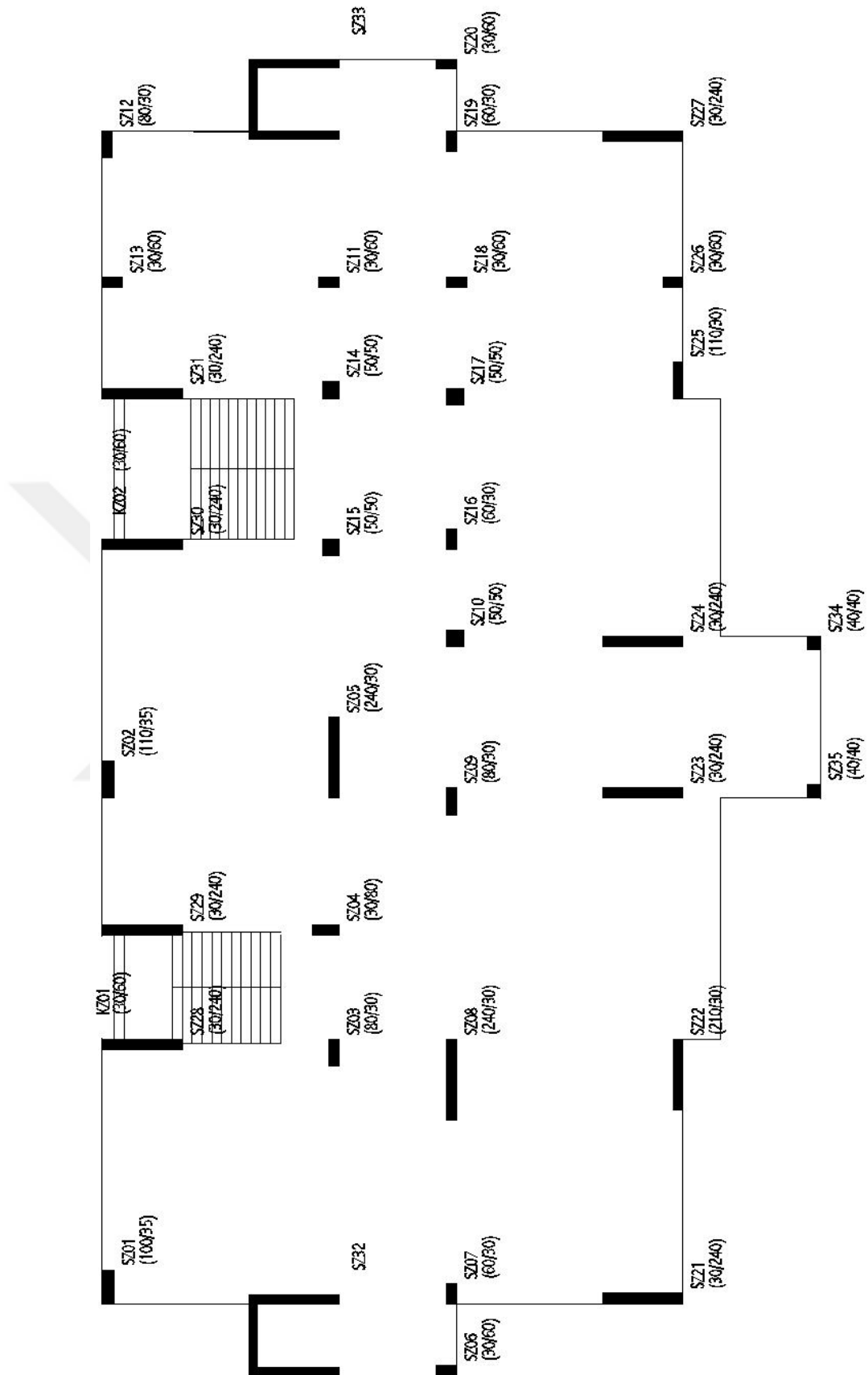


Figure 3.18. Structural plan for flat flooring system for 8 classrooms school in 1st and 2nd seismic zones

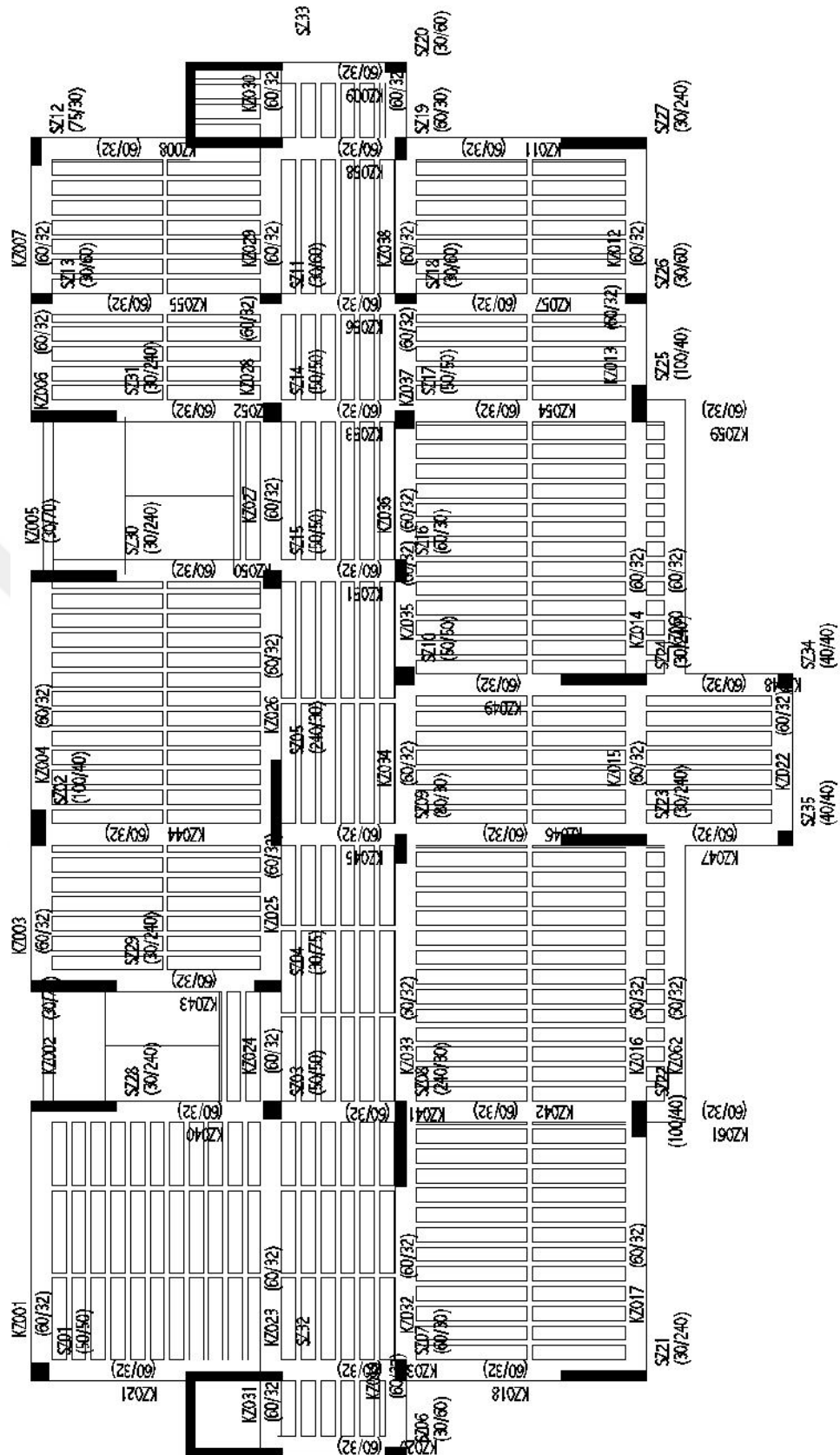


Figure 3.19. Structural plan for ribbed flooring system for 8 classrooms school in 1st and 2nd seismic zones

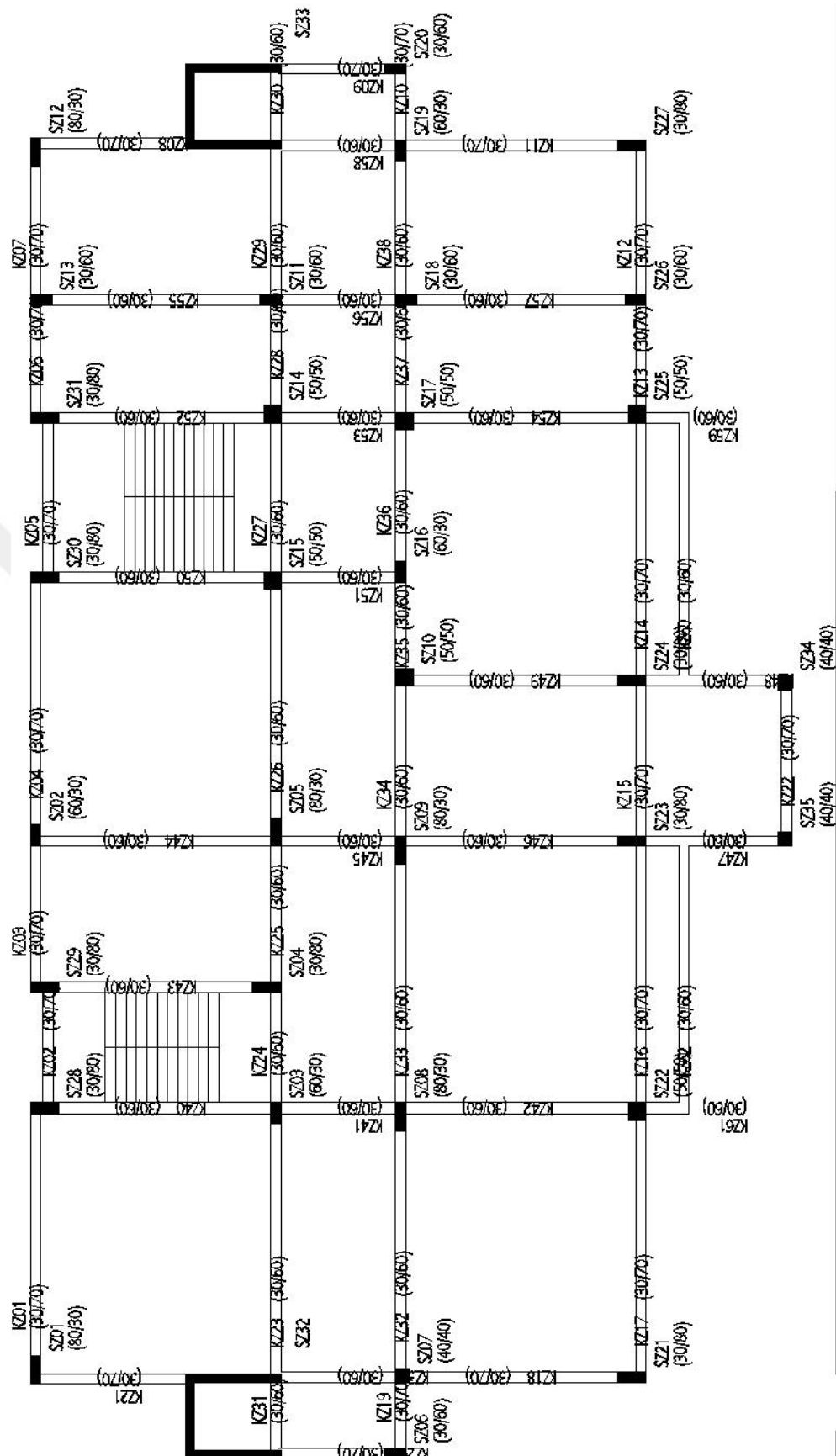


Figure 3.20. Structural plan for solid flooring system for 8 classrooms school in 3rd and 4th seismic zones

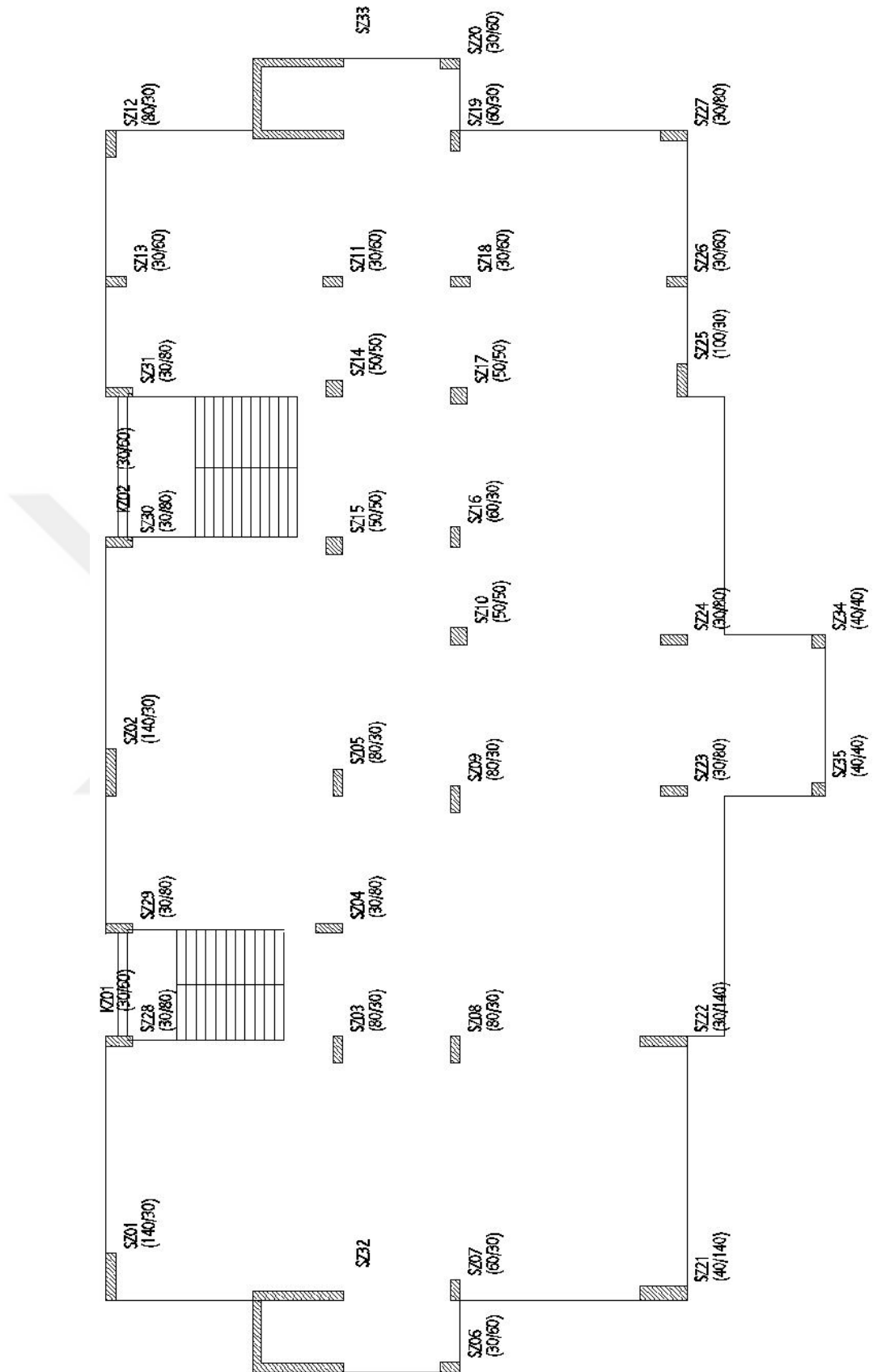


Figure 3.21. Structural plan for flat flooring system for 8 classrooms school in 3rd and 4th seismic zones

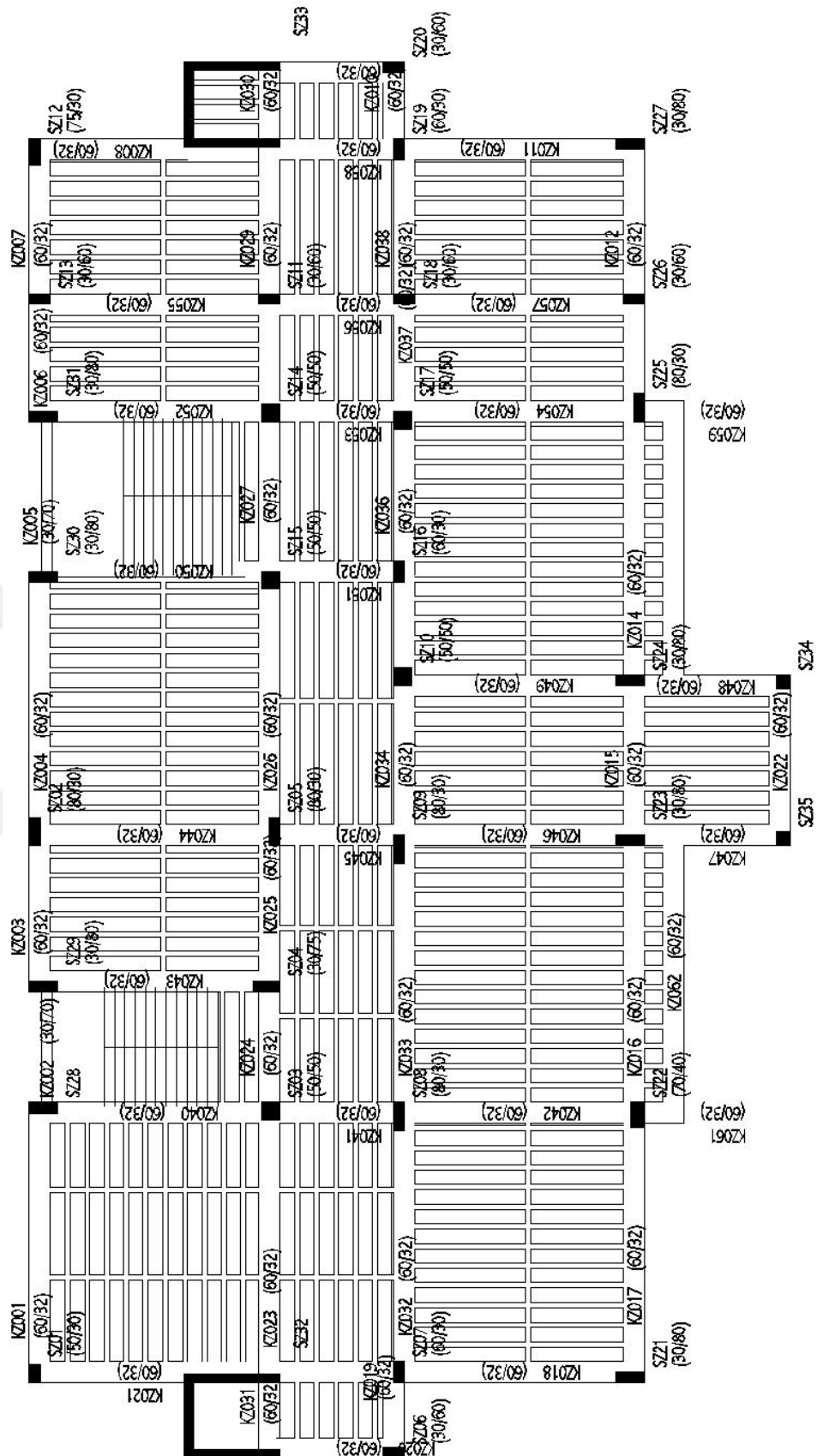


Figure 3.22. Structural plan for ribbed flooring system for 8 classrooms school in 3rd and 4th seismic zones

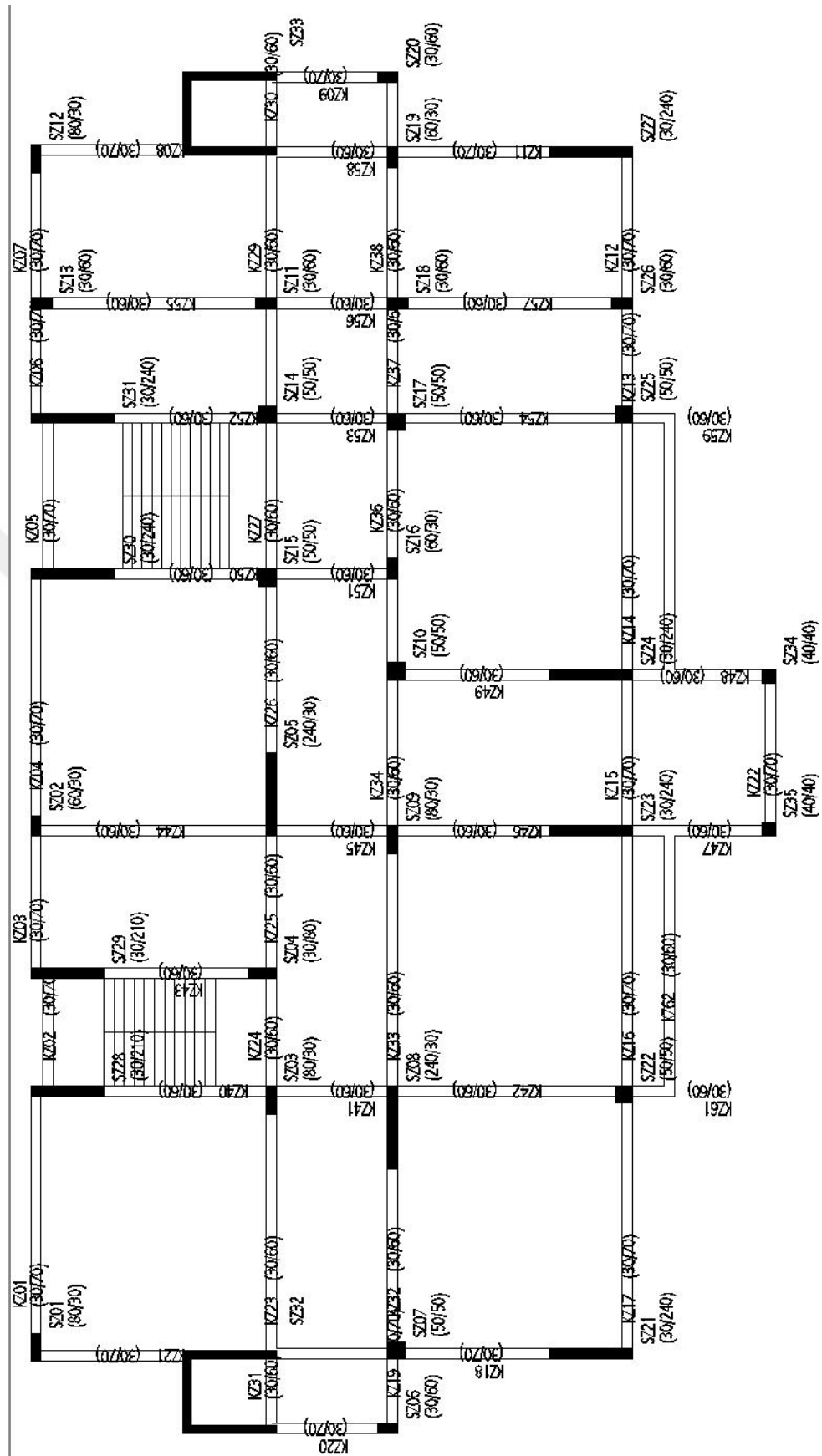


Figure 3.23. Structural plan for solid flooring system for 16 classrooms school in 1st and 2nd seismic zones

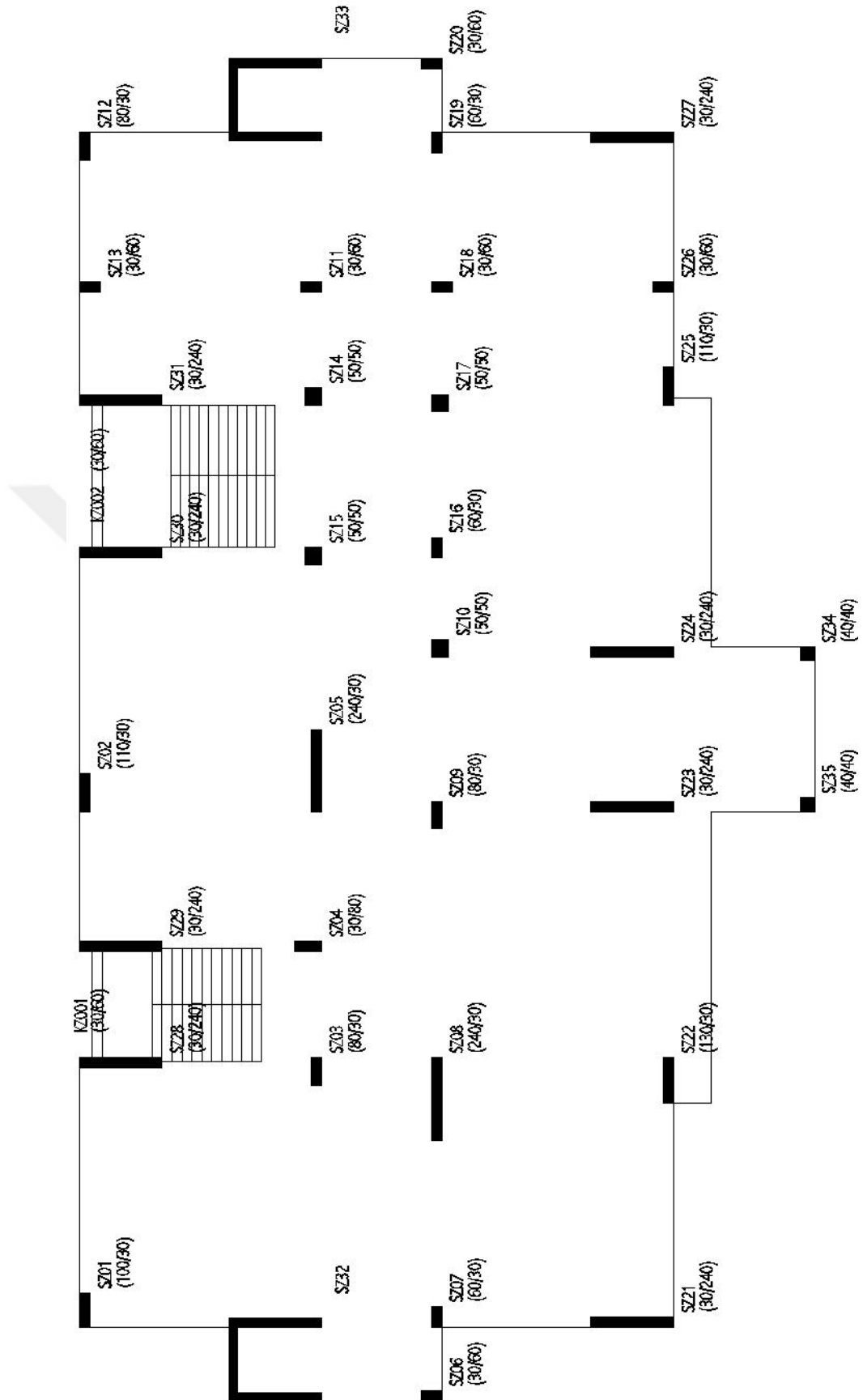


Figure 3.24. Structural plan for flat flooring system for 16 classrooms school in 1st and 2nd seismic zones

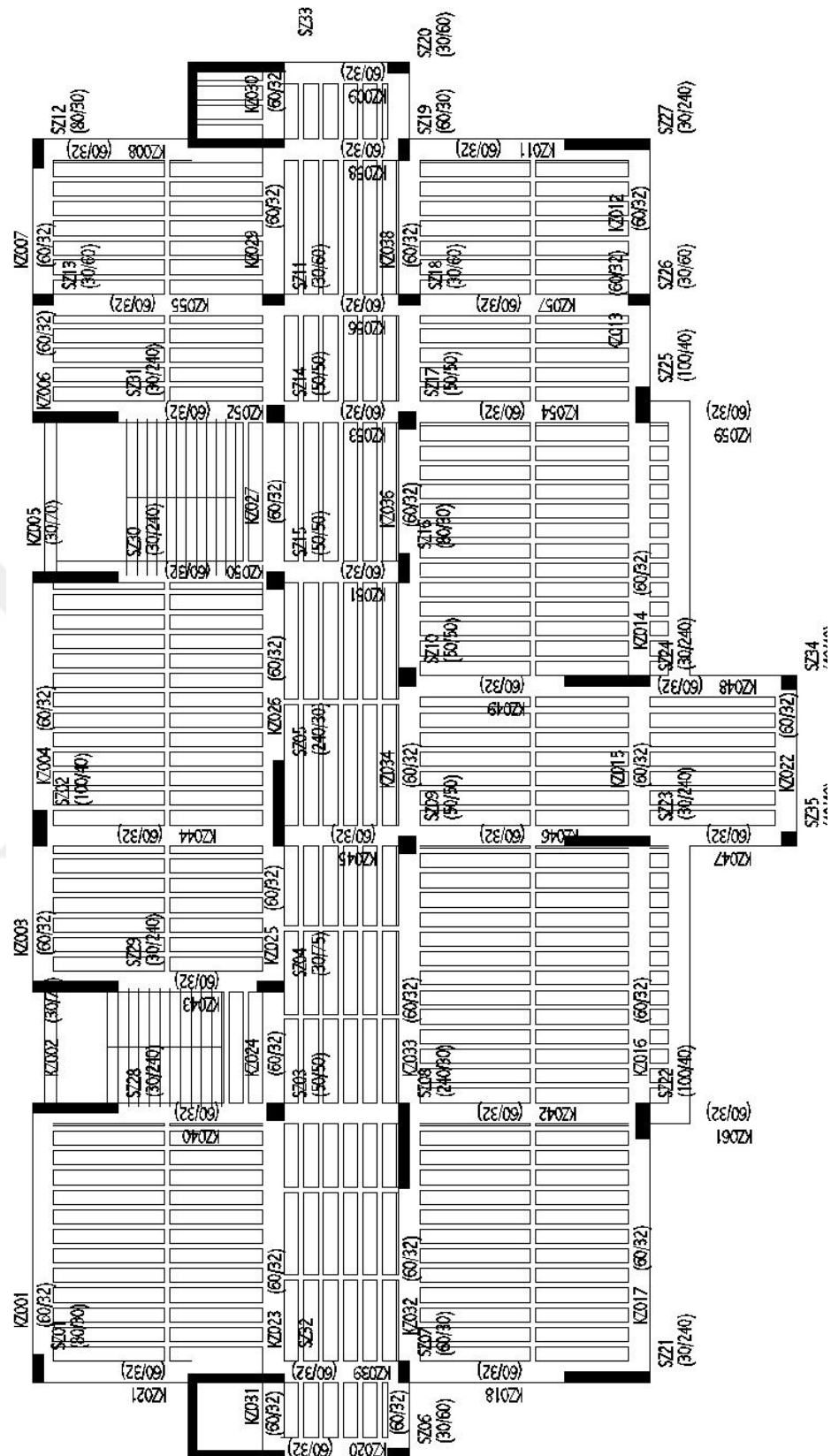


Figure 3.25. Structural plan for ribbed flooring system for 16 classrooms school in 1st and 2nd seismic zones

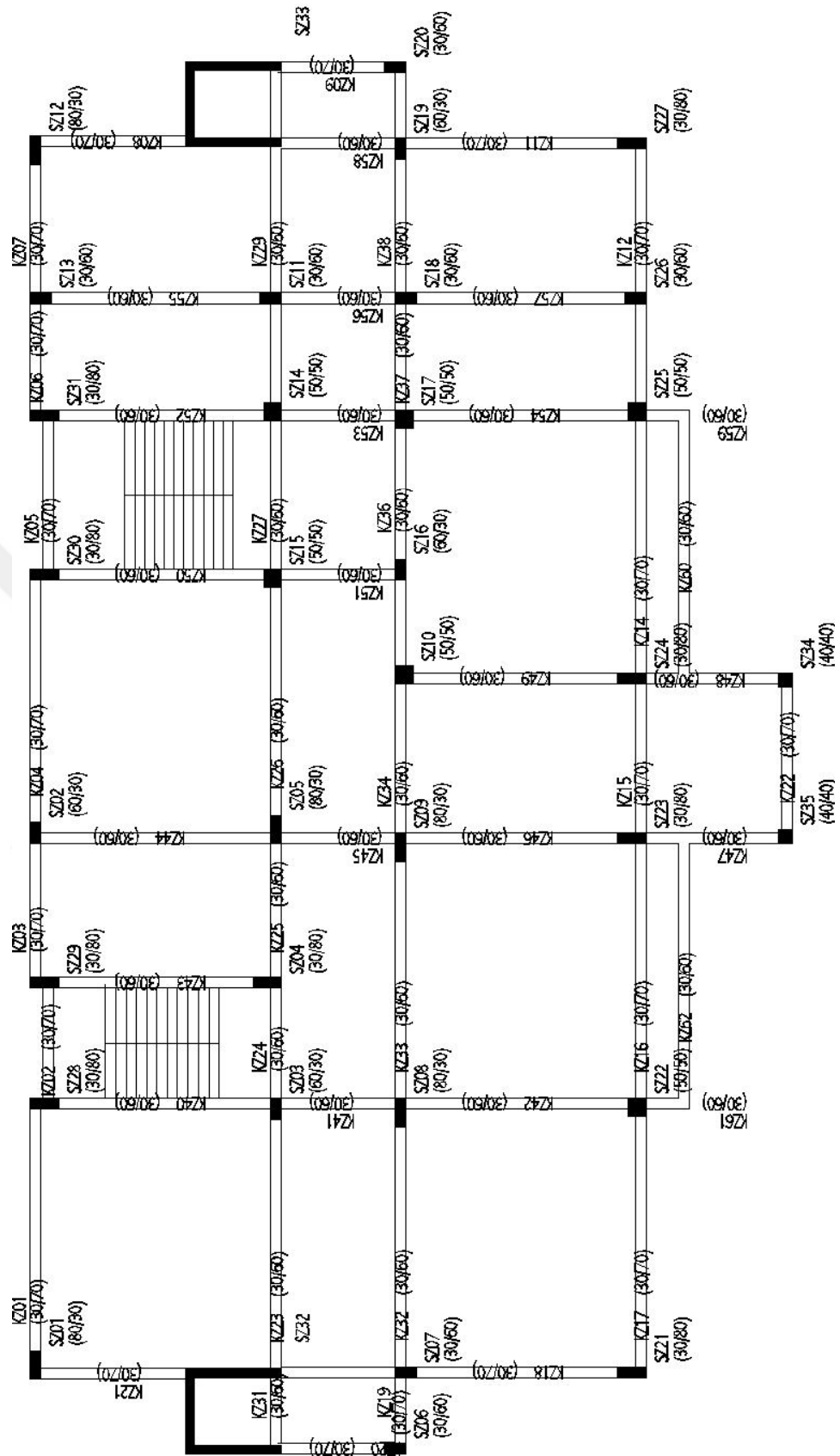


Figure 3.26. Structural plan for solid flooring system for 16 classrooms school in 3rd and 4th seismic zones

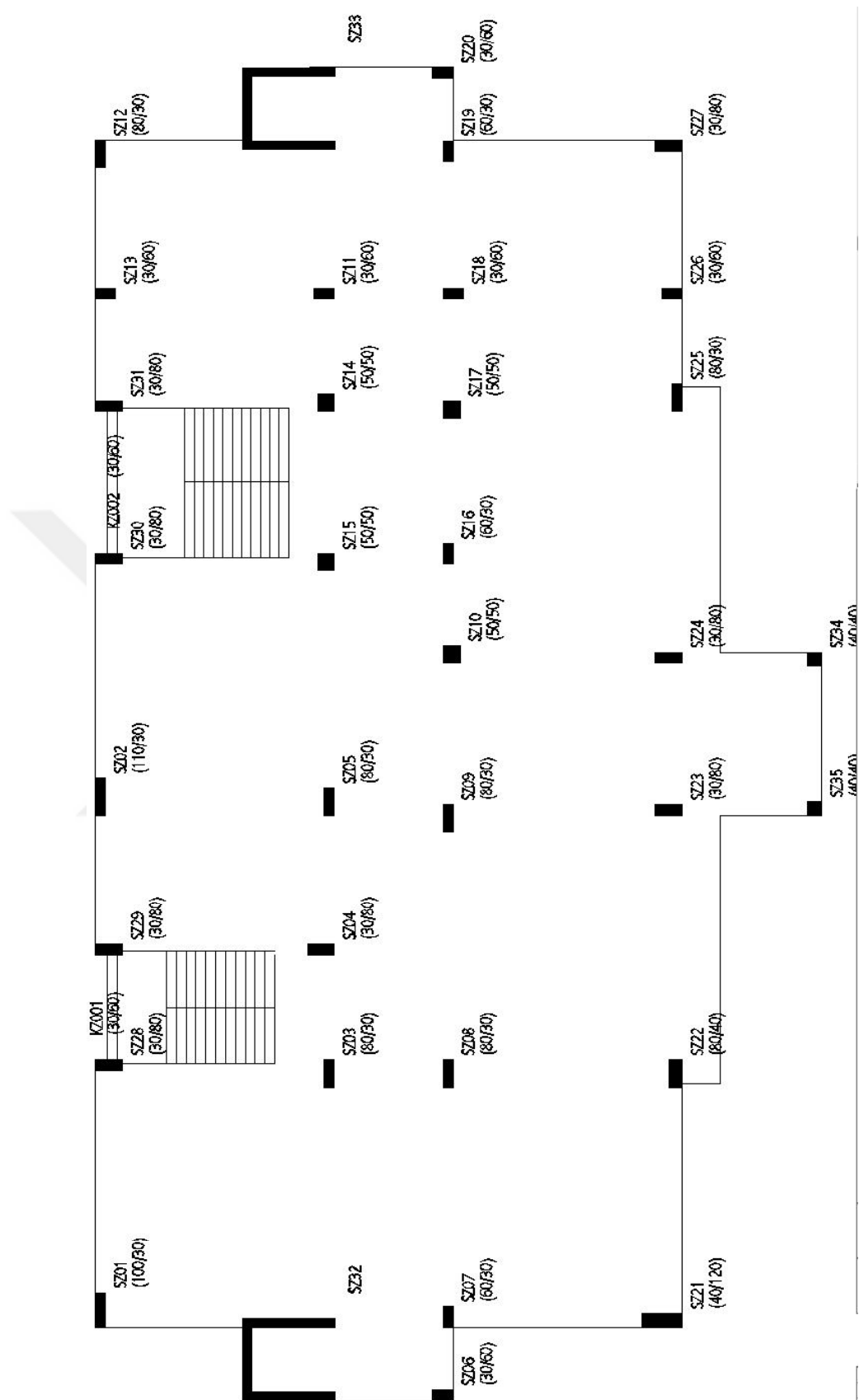


Figure 3.27. Structural plan for flat flooring system for 16 classrooms school in 3rd and 4th seismic zones

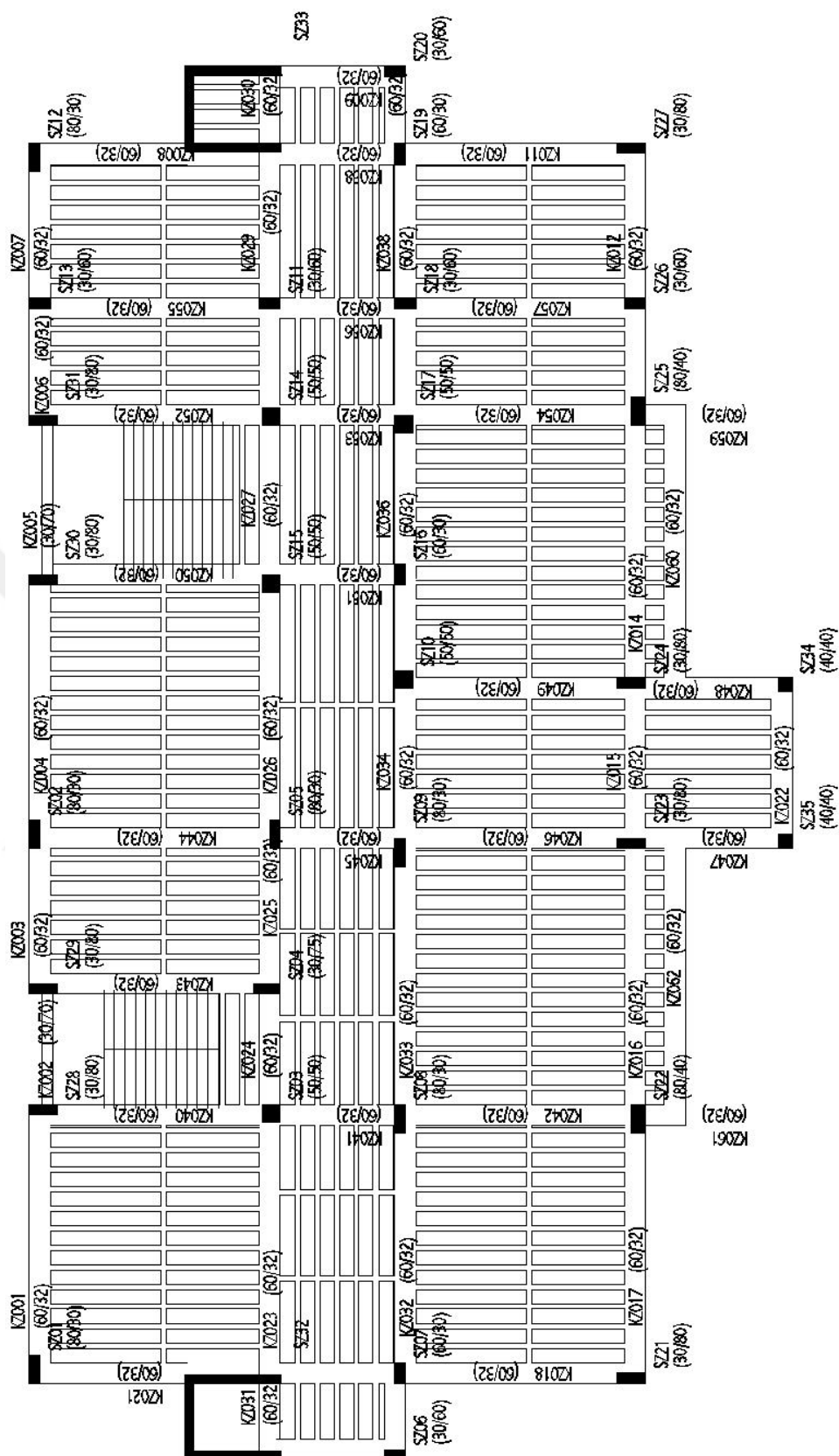


Figure 3.28. Structural plan for ribbed flooring system for 16 classrooms school in 3rd and 4th seismic zones

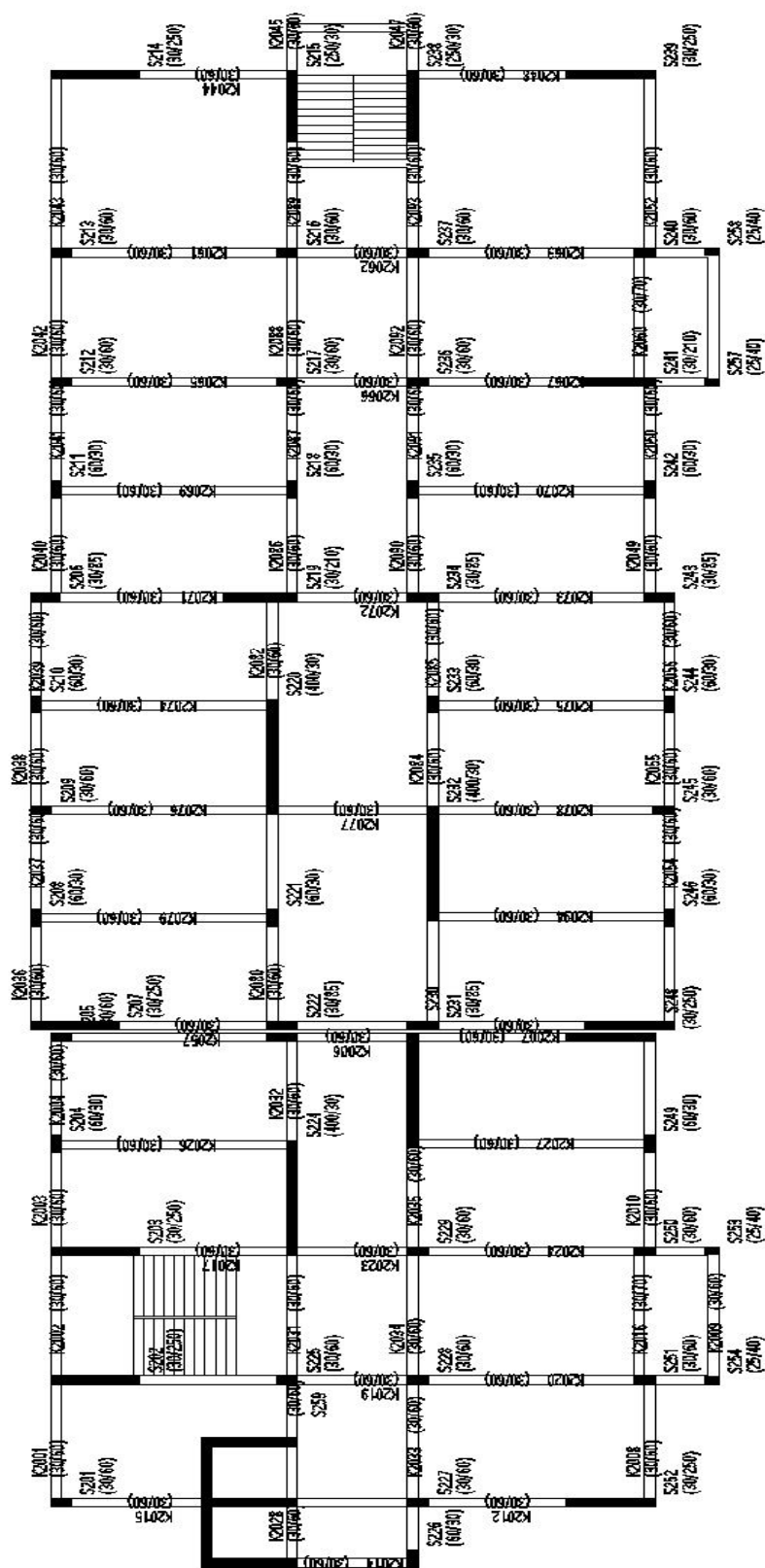


Figure 3.29. Structural plan for solid flooring system for 24 classrooms school in 1st and 2nd seismic zones

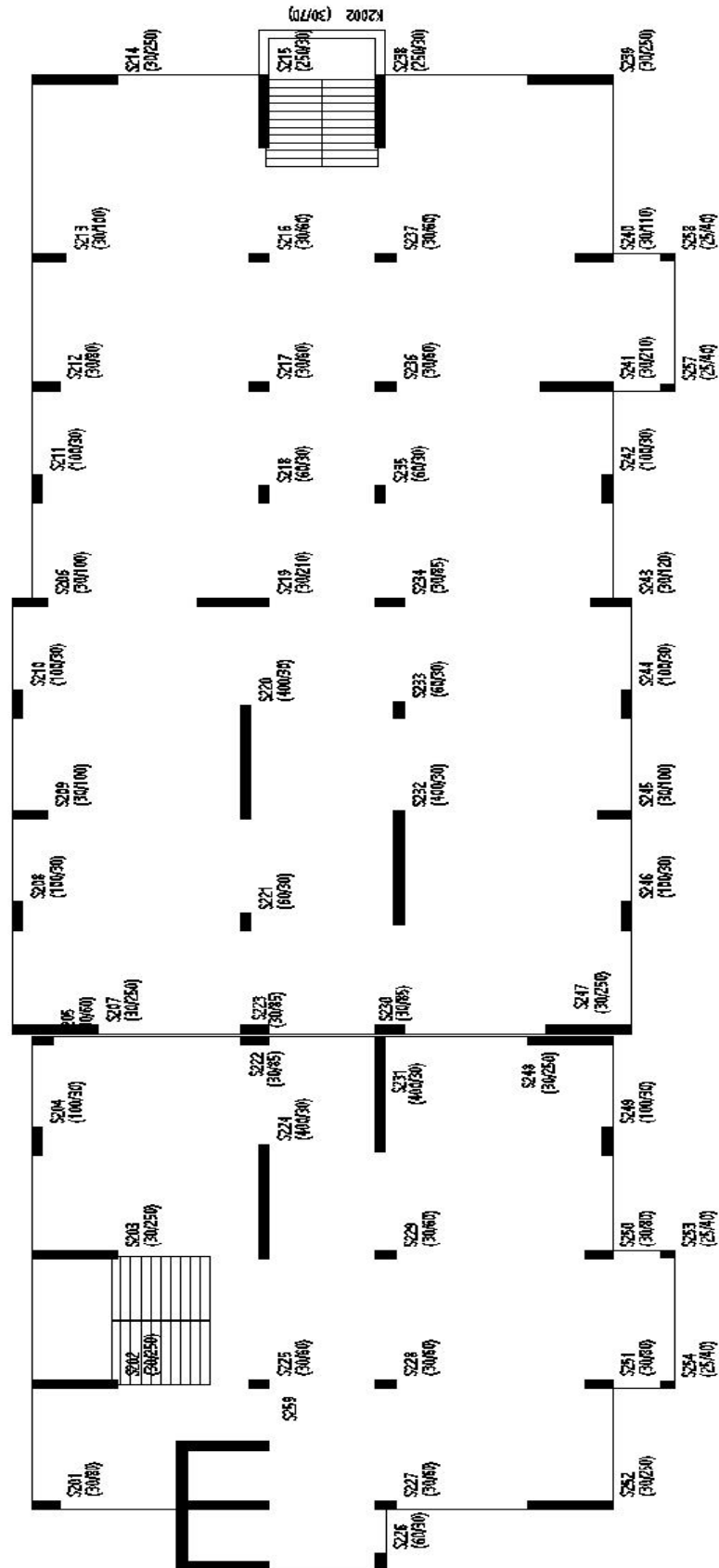


Figure 3.30. Structural plan for flat flooring system for 24 classrooms school in 1st and 2nd seismic zones

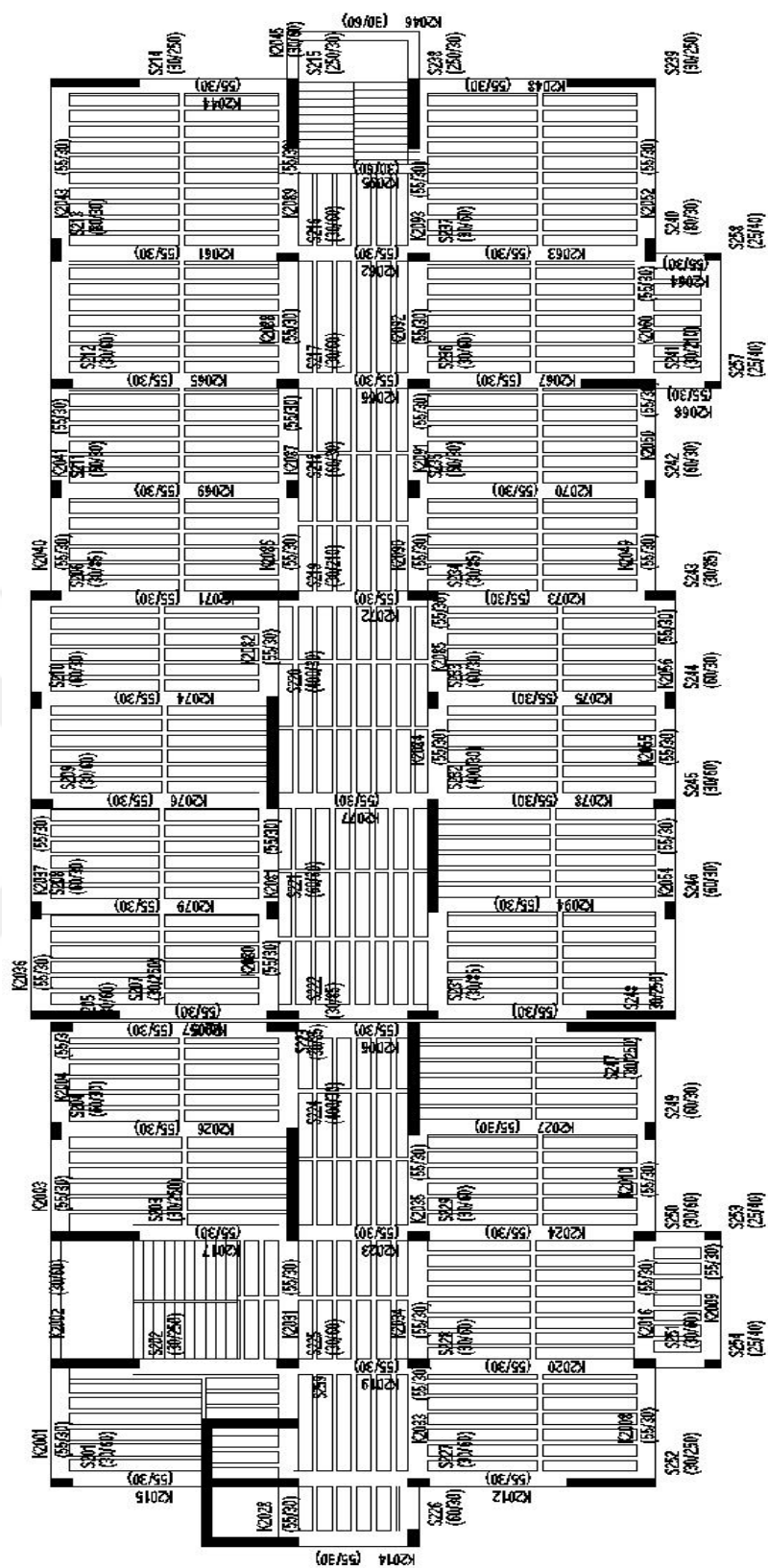


Figure 3.31. Structural plan for ribbed flooring system for 24 classrooms school in 1st and 2nd seismic zones

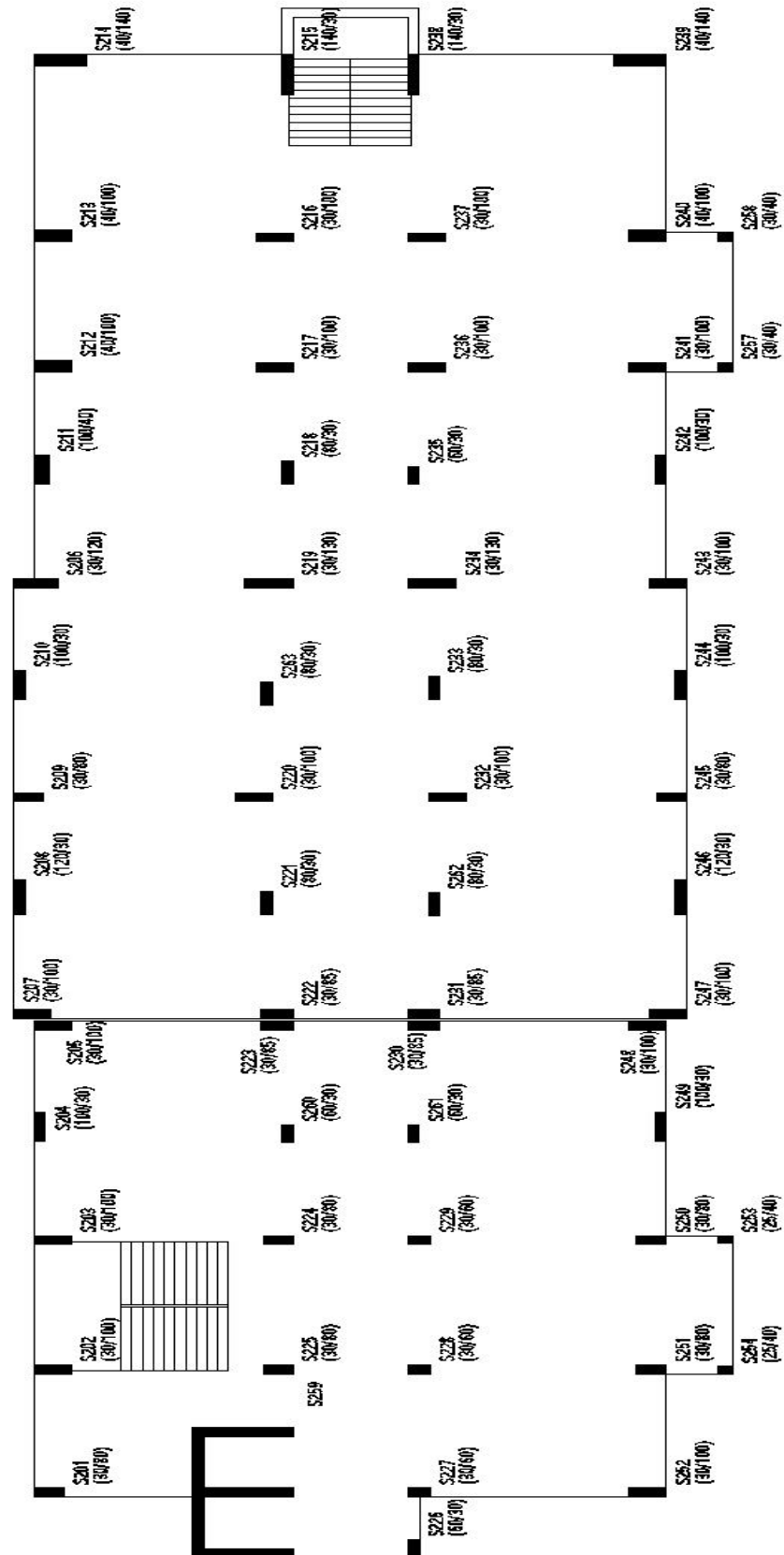


Figure 3.33. Structural plan for flat flooring system for 24 classrooms school in 3rd and 4th seismic zones

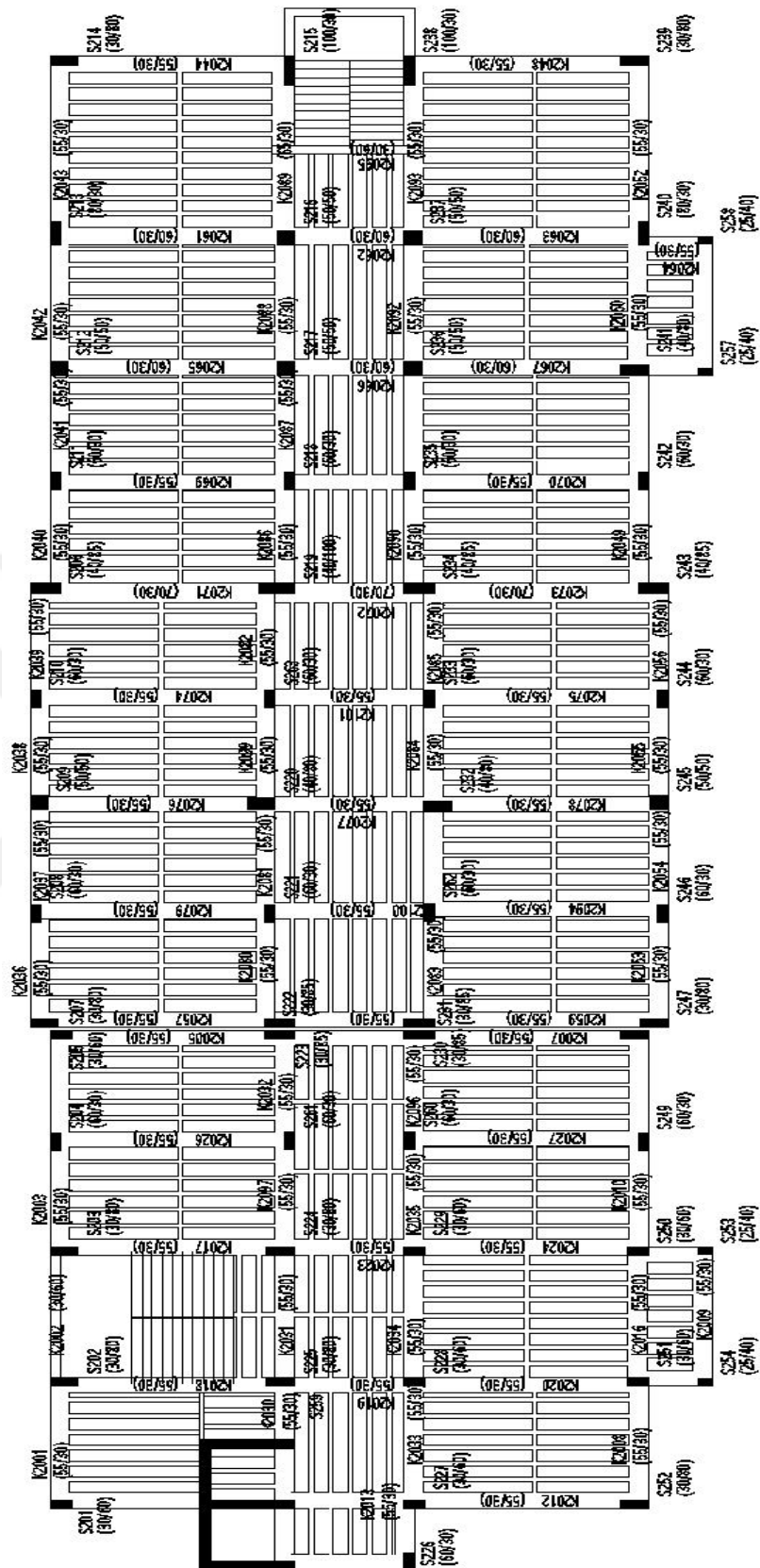


Figure 3.34. Structural plan for ribbed flooring system for 24 classrooms school in 3rd and 4th seismic zones

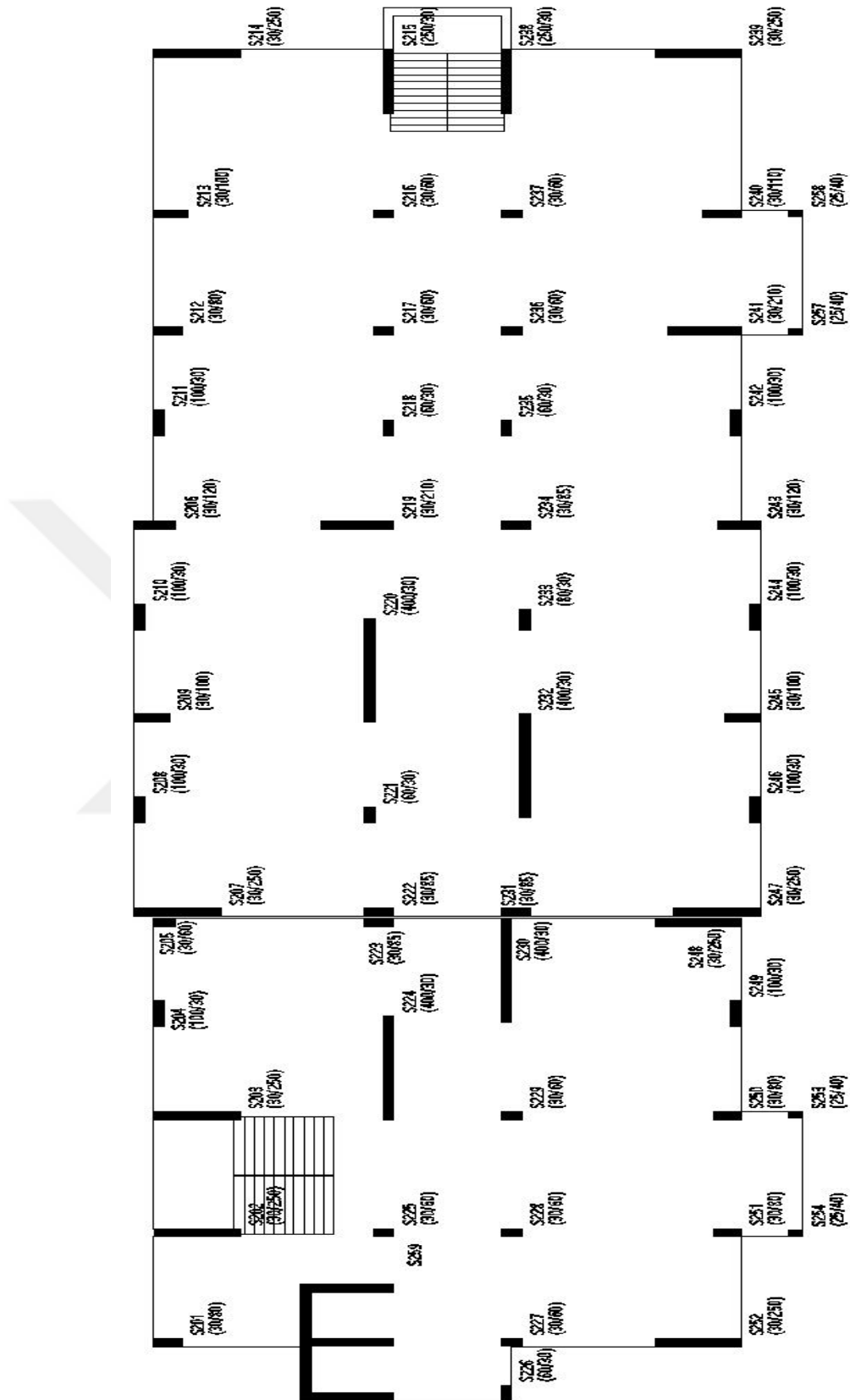


Figure 3.36. Structural plan for flat flooring system for 32 classrooms school in 1st and 2nd seismic zones

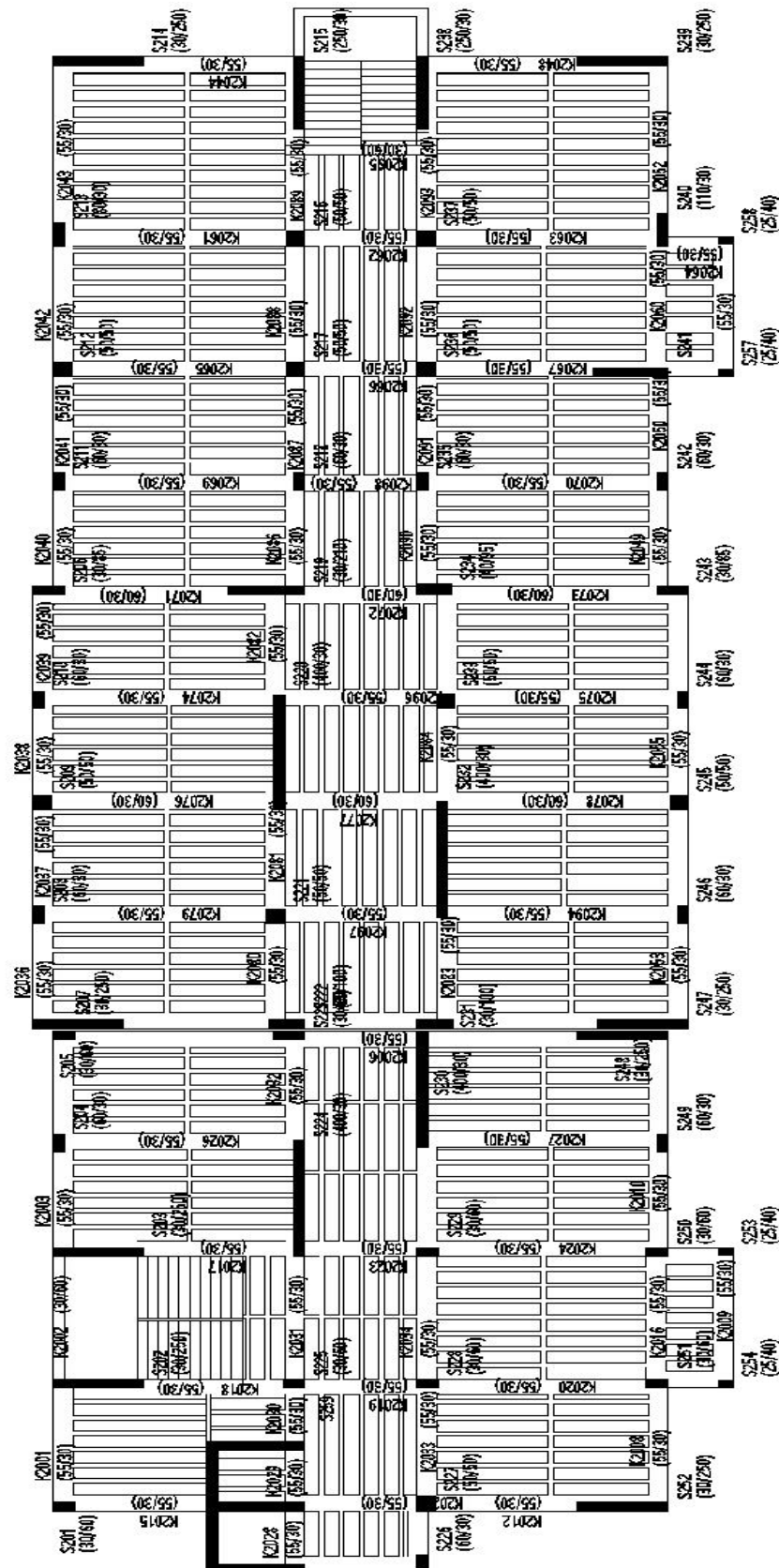


Figure 3.37. Structural plan for ribbed flooring system for 32 classrooms school in 1st and 2nd seismic zones

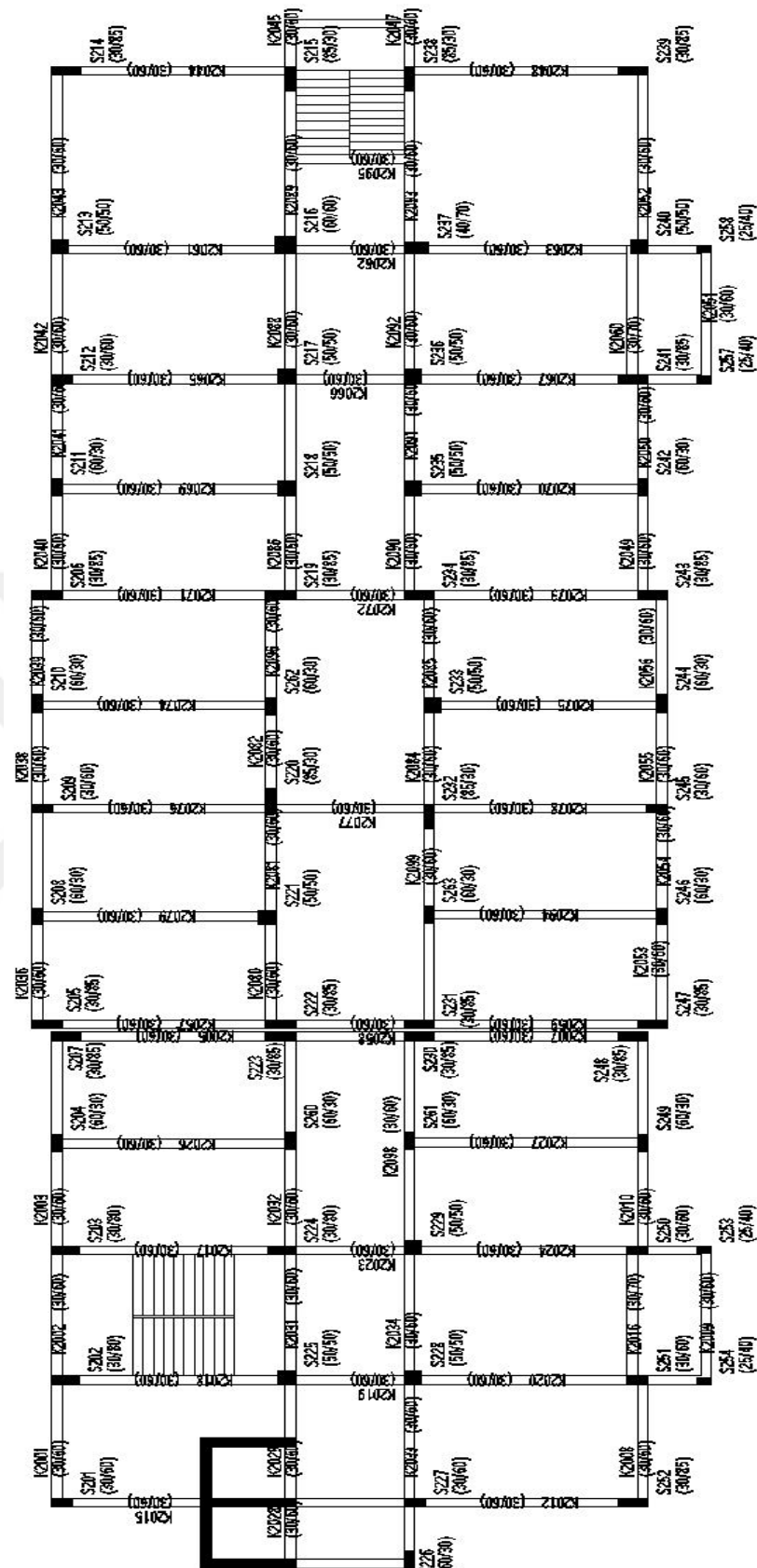


Figure 3.38. Structural plan for solid flooring system for 32 classrooms school in 3rd and 4th seismic zones

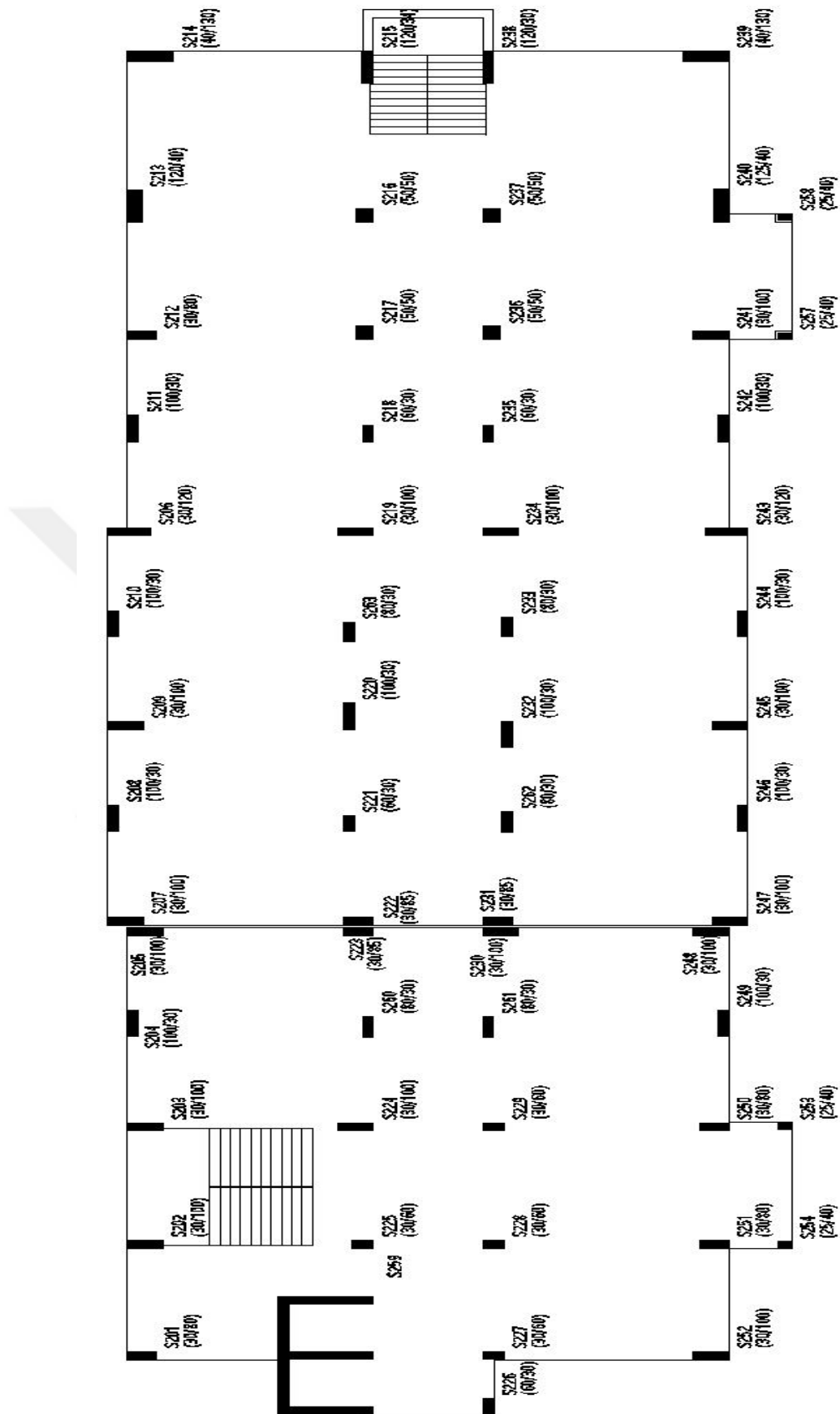


Figure 3.39. Structural plan for flat flooring system for 32 classrooms school in 3rd and 4th seismic zones

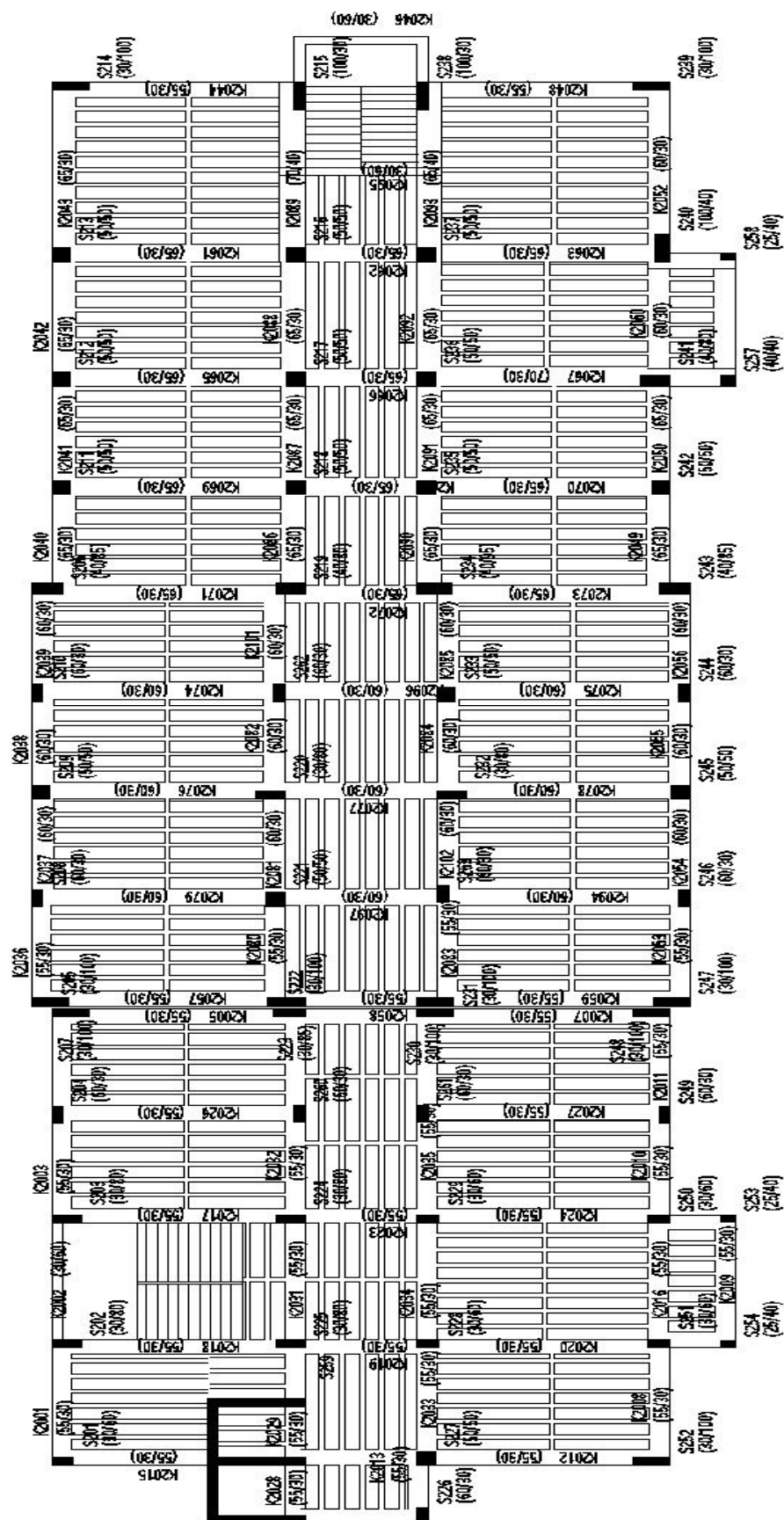


Figure 3.40. Structural plan for ribbed flooring system for 32 classrooms school in 3rd and 4th seismic zones

As seen in the previous figures, the school buildings are different in architectural plans, structural plans. The structural elements size are not the same in all buildings. The models is not the same in all seismic zones, as well as the ductility in all buildings types. The result analysis of all models will be showed and discussed in the next chapter.



4. RESULTS AND DISCUSSION

In this study, all models were modeled and analyzed by using STA4CAD software program, according to TS500 and Turkish Earthquake Code 2007 by considering the seismic zones in Turkey (1st, 2nd, 3rd, and the 4th seismic zone) and soil types that were mentioned in code (Z1, Z2, Z3, and Z4). Preliminary sizing and structural analysis of all the structural elements of the models were carried out with the aid of the STA4CAD Ver.13.1 analysis program.

4.1. Results of Structural Analysis and Materials Quantities for all Models

The results that came out from the program were plentiful. But some analysis results that are important for this study will be presented in this chapter. The results are the period of seismic in both directions, weight of structure, seismic forces in X and Y direction, seismic reduction factor, ratio of shear walls that resist seismic forces, and the quantities of structural materials like formwork, concrete, and steel for all structures are given in following tables.

The results are showed differences in materials quantities between models due to the differences in seismic zones, soil types, and flooring systems. In 8 classroom's school models, according to concrete quantities, the results in all models show the ribbed flooring system require the least amount of concrete, while the flat flooring system buildings require the most amount of concrete. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), solid flooring system require concrete 4.38% more than ribbed flooring system, while flat slab require concrete 13.3% more than ribbed flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), solid flooring system require concrete 5.49% more than ribbed flooring system, while flat slab require concrete 13.9% more than ribbed flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), solid flooring system require concrete 4.64% more than ribbed flooring system, while flat slab require concrete 12.82% more than ribbed flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), solid flooring system require concrete 4.22% more than ribbed flooring system, while flat slab require concrete 13.16% more than ribbed flooring system building.

According to formwork quantities, the results in all models show the ribbed flooring system require the least amount of formwork, while the solid flooring system

buildings require the most amount of formwork. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), flat flooring system require formwork 1.40% more than ribbed flooring system, while solid slab require formwork 13.41% more than ribbed flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), flat flooring system require formwork 1.40% more than ribbed flooring system, while solid flooring system building require formwork 15.8% more than ribbed flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), flat flooring system require formwork 1.40% more than ribbed flooring system, while solid slab require formwork 13.42% more than ribbed flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), flat flooring system buildings require formwork 1.32% more than ribbed flooring system, while solid flooring system building require formwork 15.70% more than ribbed flooring system building.

According to steel quantities, the results in all models show the ribbed flooring system require the most amount of steel. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), flat flooring system require steel 17.40% less than ribbed flooring system, while solid slab require steel 14.1% less than ribbed flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), the solid flooring system require the least amount of steel. Flat flooring system require steel 2.27% more than solid flooring system, while ribbed flooring system building require steel 15.89% more than solid flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), the flat flooring system require the least amount of steel. Ribbed flooring system require steel 17.05% more than flat flooring system, while solid slab require steel 1.06% more than flat flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), the solid flooring system require the least amount of steel. Flat flooring system buildings require steel 3.49% more than solid flooring system, while ribbed flooring system building require formwork 18.18% more than solid flooring system building.

In 16 classroom's school models, according to concrete quantities, the results in all models show the ribbed flooring system require the least amount of concrete, while the flat flooring system buildings require the most amount of concrete. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), solid flooring

system require concrete 4.49% more than ribbed flooring system, while flat slab require concrete 13.25% more than ribbed flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), solid flooring system require concrete 5.6% more than ribbed flooring system, while flat slab require concrete 13.61% more than ribbed flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), solid flooring system require concrete 3.84% more than ribbed flooring system, while flat slab require concrete 12.17% more than ribbed flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), solid flooring system require concrete 3.94% more than ribbed flooring system, while flat slab require concrete 12.24% more than ribbed flooring system building.

According to formwork quantities, the results in all models show the ribbed flooring system require the least amount of formwork, while the solid flooring system buildings require the most amount of formwork. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), flat flooring system require formwork 0.77% more than ribbed flooring system, while solid slab require formwork 14.01% more than ribbed flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), flat flooring system require formwork 0.1% more than ribbed flooring system, while solid flooring system building require formwork 16.48% more than ribbed flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), flat flooring system require formwork 0.87% more than ribbed flooring system, while solid slab require formwork 14.9% more than ribbed flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), flat flooring system buildings require formwork 0.22% more than ribbed flooring system, while solid flooring system building require formwork 16.30% more than ribbed flooring system building.

According to steel quantities, the results in all models show the ribbed flooring system require the most amount of steel. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), flat flooring system require steel 4.23% more than solid flooring system, while ribbed slab require steel 21.17% more than solid flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), flat flooring system require steel 3.66% more than solid flooring system, while ribbed flooring system building require steel 16.78% more than solid flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), flat flooring system require steel 5.39% more than solid flooring system, while

ribbed slab require steel 22% more than solid flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), flat flooring system buildings require steel 3.69% more than solid flooring system, while ribbed flooring system building require steel 16.50% more than solid flooring system building.

In 24 classroom's school models, according to concrete quantities, the results in all models show the ribbed flooring system require the least amount of concrete, while the flat flooring system buildings require the most amount of concrete. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), solid flooring system require concrete 4.89% more than ribbed flooring system, while flat slab require concrete 10.63 % more than ribbed flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), solid flooring system require concrete 4.96% more than ribbed flooring system, while flat slab require concrete 12.41% more than ribbed flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), solid flooring system require concrete 5.12% more than ribbed flooring system, while flat slab require concrete 10.37% more than ribbed flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), solid flooring system require concrete 4.34% more than ribbed flooring system, while flat slab require concrete 11.69% more than ribbed flooring system building.

According to formwork quantities, the results in all models show the ribbed flooring system require the least amount of formwork, while the solid flooring system buildings require the most amount of formwork. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), flat flooring system require formwork 0.97% more than ribbed flooring system, while solid slab require formwork 13.61% more than ribbed flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), flat flooring system require formwork 3.67% more than ribbed flooring system, while solid flooring system building require formwork 16.18% more than ribbed flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), flat flooring system require formwork 0.96% more than ribbed flooring system, while solid slab require formwork 13.5% more than ribbed flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), flat flooring system buildings require formwork 3% more than ribbed flooring system, while solid flooring system building require formwork 16.10% more than ribbed flooring system building.

According to steel quantities, the results in all models show the flat flooring system require the most amount of steel. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), flat flooring system require steel 26.37% more than solid flooring system, while ribbed slab require steel 16.10% more than solid flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), flat flooring system require steel 31.87 % more than solid flooring system, while ribbed flooring system building require steel 18.98% more than solid flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), flat flooring system require steel 28.3 % more than solid flooring system, while ribbed slab require steel 18.42% more than solid flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), flat flooring system buildings require steel 31.72% more than solid flooring system, while ribbed flooring system building require steel 19.68% more than solid flooring system building.

In 32 classroom's school models, according to concrete quantities, the results in all models show the ribbed flooring system require the least amount of concrete, while the flat flooring system buildings require the most amount of concrete. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), solid flooring system require concrete 5.30 % more than ribbed flooring system, while flat slab require concrete 10.34 % more than ribbed flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), solid flooring system require concrete 4.50% more than ribbed flooring system, while flat slab require concrete 10.41% more than ribbed flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), solid flooring system require concrete 4.86% more than ribbed flooring system, while flat slab require concrete 9.91 % more than ribbed flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), solid flooring system require concrete 3.84% more than ribbed flooring system, while flat slab require concrete 10.32% more than ribbed flooring system building.

According to formwork quantities, the results in all models show the ribbed flooring system require the least amount of formwork, while the solid flooring system buildings require the most amount of formwork. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), flat flooring system require formwork 0.43% more than ribbed flooring system, while solid slab require formwork 14.13% more than ribbed flooring system building. In the fourth seismic zone and the first type

of soil (Z1, 4th seismic zone), flat flooring system require formwork 1.36% more than ribbed flooring system, while solid flooring system building require formwork 14.13% more than ribbed flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), flat flooring system require formwork 0.43% more than ribbed flooring system, while solid slab require formwork 14.11% more than ribbed flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), flat flooring system buildings require formwork 1.3% more than ribbed flooring system, while solid flooring system building require formwork 15.85% more than ribbed flooring system building.

According to steel quantities, the results in all models show the solid flooring system require the least amount of steel. For example, in the first seismic zone and the first type of soil (Z1, 1st seismic zone), flat flooring system require steel 19.37% more than solid flooring system, while ribbed slab require steel 17.12% more than solid flooring system building. In the fourth seismic zone and the first type of soil (Z1, 4th seismic zone), flat flooring system require steel 24.77 % more than solid flooring system, while ribbed flooring system building require steel 19.38% more than solid flooring system building. In the first seismic zone and the fourth type of soil (Z4, 1st seismic zone), flat flooring system require steel 25.47 % more than solid flooring system, while ribbed slab require steel 22.04% more than solid flooring system building. In the fourth seismic zone and the fourth type of soil (Z4, 4th seismic zone), flat flooring system buildings require steel 26.18% more than solid flooring system, while ribbed flooring system building require steel 23.10% more than solid flooring system building.

Table 4.1. Analysis results and materials quantities for 8 Classroom's school buildings that applied in the first type of soil – Z1

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
Type of seismic zone	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
T x (s)	0.21	0.21	0.22	0.22	0.23	0.23	0.25	0.25	0.24	0.24	0.25	0.25
T y (s)	0.18	0.18	0.21	0.21	0.20	0.20	0.24	0.24	0.20	0.20	0.24	0.24
W (t)	2982.15	2976	2898.65	2898.65	3158.78	3148.8	3055.51	3055	3115.1	3112.28	3028.54	3028
Vt x (t)	397.85	297.75	219.95	109.98	437.77	326.68	235.49	117.75	429.50	321.65	220.73	109.99
Vt y (t)	397.85	297.75	219.95	109.98	437.77	326.68	235.49	117.75	429.50	321.65	220.73	109.99
α s in x direction	0.64	0.65	0.59	0.59	0.69	0.69	0.57	0.57	0.65	0.65	0.66	0.67
α s in y direction	0.85	0.85	0.69	0.69	0.90	0.90	0.73	0.73	0.91	0.91	0.78	0.78
R	6.6	6.6	5.77	5.77	6.4	6.4	5.71	5.71	6.36	6.36	5.98	6
Formwork (m ²)	4892	4885.2	4612	4612	4374	4372	4038.5	4038.1	4313.2	4312.3	3983	3982
Concrete (m ³)	1054.3	1046.4	998.3	998.3	1145	1133	1082.8	1077.5	1010	998.3	952	946
Steel 8-12 mm (t)	43	41.5	40.9	40	41.2	39.2	41	41	48.1	46.7	48	47
Steel 12-50 mm (t)	49.8	49.3	48.8	48	50.8	51	50	49	60	59	56	55

Table 4.2. Analysis results and materials quantities for 8 Classroom's school buildings that applied in the second type of soil – Z2

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
Type of seismic zone	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
T x (s)	0.21	0.21	0.22	0.22	0.23	0.23	0.25	0.25	0.24	0.24	0.25	0.25
T y (s)	0.18	0.18	0.21	0.21	0.20	0.20	0.24	0.24	0.20	0.20	0.24	0.24
W (t)	2982.2	2976	2898.65	2898.65	3158.78	3148.8	3055.51	3055	3115.1	3112.28	3028.54	3028
Vt x (t)	397.85	297.75	219.95	109.98	437.77	326.68	235.49	117.75	429.50	321.65	220.73	110.36
Vt y (t)	397.85	297.75	219.95	109.98	437.77	326.68	235.49	117.75	429.50	321.65	220.73	110.36
α s in x direction	0.64	0.65	0.59	0.59	0.69	0.69	0.57	0.57	0.65	0.65	0.66	0.66
α s in y direction	0.85	0.85	0.69	0.69	0.90	0.90	0.73	0.73	0.91	0.91	0.78	0.78
R	6.6	6.6	5.77	5.77	6.4	6.4	5.71	5.71	6.36	6.36	5.98	5.98
Formwork (m ²)	4892.3	4885.8	4613.5	4613	4376	4374	4039.5	4039	4314	4313	3984	3983
Concrete (m ³)	1058	1056.6	1015	1015	1150	1144.5	1094.5	1094	1015	1010	963	963
Steel 8-12 mm (t)	43	41.5	40	40	41.2	39.5	41	39	49.6	48	47	46
Steel 12-50 mm (t)	50.1	49.5	49	46	50.7	52	51	48	58.9	58	57	57

Table 4.3. Analysis results and materials quantities for 8 Classroom's school buildings that applied in the third type of soil – Z3

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
Type of seismic zone	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
T x (s)	0.21	0.21	0.22	0.22	0.23	0.23	0.25	0.25	0.24	0.24	0.25	0.25
T y (s)	0.18	0.18	0.21	0.21	0.20	0.20	0.24	0.24	0.20	0.20	0.24	0.24
W (t)	2982.2	2976	2898.65	2898.65	3158.78	3148.8	3055.51	3055	3115.1	3112.28	3028.54	3028
Vt x (t)	397.85	297.75	219.95	109.98	437.77	326.68	235.49	117.75	429.50	321.65	220.73	110.36
Vt y (t)	397.85	297.75	219.95	109.98	437.77	326.68	235.49	117.75	429.50	321.65	220.73	110.36
α s in x direction	0.64	0.65	0.59	0.59	0.69	0.69	0.57	0.57	0.65	0.65	0.66	0.66
α s in y direction	0.85	0.85	0.69	0.69	0.90	0.90	0.73	0.73	0.91	0.91	0.78	0.78
R	6.6	6.6	5.77	5.77	6.4	6.4	5.71	5.71	6.36	6.36	5.98	5.98
Formwork (m ²)	4893	4887	4614	4613	4376	4374	4041	4040	4316	4314	3985	3984
Concrete (m ³)	1065.3	1059	1018	1017	1153	1146	1097	1096	1030	1012	966	965
Steel 8-12 mm (t)	43	41.5	40	40.2	42	39.5	41	41	49	47	47	47
Steel 12-50 mm (t)	50	49	50	48	52	52	53	49.5	62	59	58	57

Table 4.4. Analysis results and materials quantities for 8 Classroom's school buildings that applied in the fourth type of soil – Z4

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone												
T x (s)	0.21	0.21	0.22	0.22	0.23	0.23	0.25	0.25	0.24	0.24	0.25	0.25
T y (s)	0.18	0.18	0.21	0.21	0.20	0.20	0.24	0.24	0.20	0.20	0.24	0.24
W (t)	2982.2	2976	2898.65	2898.65	3158.78	3148.8	3055.51	3055	3115.1	3112.28	3028.54	3028
Vt x (t)	397.85	297.75	219.95	109.98	437.77	326.68	235.49	117.75	429.50	321.65	220.73	110.36
Vt y (t)	404.69	302.67	219.95	109.98	437.77	326.68	235.49	117.75	429.50	321.65	220.73	110.36
α s in x direction	0.64	0.65	0.59	0.59	0.69	0.69	0.57	0.57	0.65	0.65	0.66	0.66
α s in y direction	0.85	0.85	0.69	0.69	0.90	0.90	0.73	0.73	0.91	0.91	0.78	0.78
R	6.6	6.6	5.77	5.77	6.4	6.4	5.71	5.71	6.36	6.36	5.98	5.98
Formwork (m ²)	4897	4890	4617	4615	4380	4377	4043	4041	4318	4317	3987	3986
Concrete (m ³)	1126	1097	1066	1037	1214	1191	1142	1126	1076	1070	1011	995
Steel 8-12 mm (t)	44	42	41	40	42	39.7	42	41	49	48	48	47
Steel 12-50 mm (t)	51	49	50	48	52	54	55	50	61	60	58	57

Table 4.5. Analysis results and materials quantities for 16 Classroom's school buildings that applied in the first type of soil – Z1

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
Type of seismic zone	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
T x (s)	0.32	0.32	0.33	0.33	0.36	0.36	0.39	0.39	0.37	0.37	0.39	0.39
T y (s)	0.27	0.27	0.30	0.30	0.32	0.32	0.387	0.387	0.32	0.32	0.38	0.38
W (t)	3655.7	3655.7	3532.86	3532.86	3897.57	3897.57	3793.29	3793.29	3779.15	3779.15	3665.45	3665.45
Vt x (t)	524.68	393.51	286.57	143.29	518.25	388.69	268.06	134.03	493.15	369.86	254.10	127.05
Vt y (t)	549.10	411.82	304.03	152.02	573.72	430.29	270.46	135.23	559.57	419.67	258.36	129.18
α s in x direction	0.60	0.60	0.56	0.56	0.58	0.58	0.56	0.56	0.59	0.59	0.60	0.60
α s in y direction	0.83	0.83	0.66	0.66	0.89	0.89	0.73	0.73	0.89	0.89	0.75	0.75
R	6.68	6.68	5.68	5.68	6.44	6.44	5.68	5.68	6.44	6.44	5.8	5.8
Formwork (m ²)	6153	6152	5791	5790.8	5436	5436	4980	4980	5394	5394	4971	4971
Concrete (m ³)	1302	1301	1240	1240	1411	1411	1335	1335	1246	1246	1175	1175
Steel 8-12 mm (t)	57	55.7	55	53	53	53	53	52	61	60.5	59	58
Steel 12-50 mm (t)	61	57.7	57	56	70	63	62	61	82	75.2	71.3	69.5

Table 4.6. Analysis results and materials quantities for 16 Classroom's school buildings that applied in the second type of soil – Z2

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone												
T x (s)	0.32	0.32	0.33	0.33	0.36	0.36	0.39	0.39	0.37	0.37	0.39	0.39
T y (s)	0.27	0.27	0.30	0.30	0.32	0.32	0.387	0.387	0.32	0.32	0.38	0.38
W (t)	3655.7	3655.7	3532.86	3532.86	3897.57	3897.57	3793.29	3793.29	3779.15	3779.15	3665.45	3665.45
Vt x (t)	549.10	411.82	311.06	155.53	602.06	451.54	331.83	165.92	586.49	439.86	315.10	157.55
Vt y (t)	549.10	411.82	311.06	155.53	602.06	451.54	331.83	165.92	586.49	439.86	315.10	157.55
α s in x direction	0.60	0.60	0.56	0.56	0.58	0.58	0.56	0.56	0.59	0.59	0.60	0.60
α s in y direction	0.83	0.83	0.66	0.66	0.89	0.89	0.73	0.73	0.89	0.89	0.75	0.75
R	6.68	6.68	5.68	5.68	6.44	6.44	5.68	5.68	6.44	6.44	5.8	5.8
Formwork (m ²)	6154	6153	5792	5792	5438	5438	4982	4981	5397	5396	4973	4973
Concrete (m ³)	1316	1315	1260	1260	1429	1429	1357	1356	1263	1262	1197	1197
Steel 8-12 mm (t)	57	55.7	54	53	52	53.2	53	52	61	60	58.8	59
Steel 12-50 mm (t)	62	58.5	56	55.7	70	63	62	61	80	76	72.8	69

Table 4.7. Analysis results and materials quantities for 16 Classroom's school buildings that applied in the third type of soil – Z3

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone												
T x (s)	0.32	0.32	0.33	0.33	0.36	0.36	0.39	0.39	0.37	0.37	0.39	0.39
T y (s)	0.27	0.27	0.30	0.30	0.32	0.32	0.387	0.387	0.32	0.32	0.38	0.38
W (t)	3655.7	3655.7	3532.86	3532.86	3897.57	3897.57	3793.29	3793.29	3782.56	3782.56	3665.45	3665.45
Vt x (t)	549.10	411.82	311.06	155.53	602.06	451.54	331.83	165.92	587.23	440.42	315.10	157.55
Vt y (t)	549.10	411.82	311.06	155.53	602.06	451.54	331.83	165.92	587.23	440.42	315.10	157.55
α s in x direction	0.60	0.60	0.56	0.56	0.58	0.58	0.56	0.56	0.59	0.59	0.60	0.60
α s in y direction	0.83	0.83	0.66	0.66	0.89	0.89	0.73	0.73	0.89	0.89	0.75	0.75
R	6.68	6.68	5.68	5.68	6.44	6.44	5.68	5.68	6.44	6.44	5.8	5.8
Formwork (m ²)	6156	6155	5793	5792	5440	5439	4983	4982	5398	5398	4974	4973
Concrete (m ³)	1352	1351	1268	1267	1460	1460	1378	1377	1294	1294	1216	1215
Steel 8-12 mm (t)	57	55.7	54	54	52	53	54	53	61	60	59	59.1
Steel 12-50 mm (t)	62	58.5	56	55.3	72	63	62	60	81	75	72	69

Table 4.8. Analysis results and materials quantities for 16 Classroom's school buildings that applied in the fourth type of soil – Z4

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
Type of seismic zone	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
T x (s)	0.32	0.32	0.33	0.33	0.36	0.36	0.39	0.39	0.37	0.37	0.39	0.39
T y (s)	0.27	0.27	0.30	0.30	0.32	0.32	0.387	0.387	0.32	0.32	0.38	0.38
W (t)	3655.7	3655.7	3532.86	3532.86	3897.57	3897.57	3793.29	3793.29	3776.75	3782.56	3665.45	3665.45
Vt x (t)	549.10	411.82	311.06	155.53	602.06	451.54	331.83	165.92	585.96	439.74	315.10	157.55
Vt y (t)	549.10	411.82	311.06	155.53	602.06	451.54	331.83	165.92	585.96	439.74	315.10	157.55
α s in x direction	0.60	0.60	0.56	0.56	0.58	0.58	0.56	0.56	0.59	0.59	0.60	0.60
α s in y direction	0.83	0.83	0.66	0.66	0.89	0.89	0.73	0.73	0.89	0.89	0.75	0.75
R	6.68	6.68	5.68	5.68	6.44	6.44	5.68	5.68	6.44	6.44	5.8	5.8
Formwork (m ²)	6158	6158	5795	5795	5443	5443	4985	4986	5401	5400	4976	4976
Concrete (m ³)	1399	1399	1315	1316	1511	1511	1420	1421	1347	1346	1267	1266
Steel 8-12 mm (t)	57	55.7	54	54.9	52	53	53.4	53	61	60	59	59.1
Steel 12-50 mm (t)	61	58	57	56	73	63.3	65	62	83	77	74	70.1

Table 4.9. Analysis results and materials quantities for 24 Classroom's school buildings that applied in the first type of soil – Z1

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone												
T x (s)	0.28	0.28	0.38	0.38	0.34	0.34	0.43	0.43	0.33	0.33	0.48	0.48
T y (s)	0.33	0.33	0.42	0.42	0.43	0.43	0.51	0.51	0.43	0.43	0.59	0.59
W (t)	5054.28	5054.28	4850.55	4850.55	5229.83	5229.83	5022.88	5022.88	5192.97	5192.97	5035.59	5035.59
Vt x (t)	766.65	574.99	489.18	244.59	743.48	557.61	395.99	197.99	750.10	562.58	442.61	221.31
Vt y (t)	729.25	546.49	470.68	235.34	616.48	462.36	336.74	168.37	637.66	478.24	368.29	184.15
α s in x dir (diaphragm 1)	0.86	0.86	0.77	0.77	0.86	0.86	0.79	0.79	0.89	0.89	0.83	0.83
α s in y dir (diaphragm 1)	0.75	0.75	0.50	0.50	0.82	0.82	0.60	0.60	0.83	0.83	0.61	0.61
R (diaphragm 1)	6.56	6.56	5.5	5.5	6.73	6.73	4.75	4.75	6.44	6.44	5.83	5.83
α s in x dir (diaphragm 1)	0.69	0.69	.....	.....	0.64	0.64	.....	.....	0.73	0.73	....	....
α s in y dir (diaphragm 1)	0.64	0.64	.....	.....	0.71	0.71	.....	.....	0.76	0.76	.....	.....
R (diaphragm 1)	7	7	4	4	6.9	6.9	4	4	6.96	6.96	4	4
Formwork (m ²)	8703	8703	8066	8066	7735	7735	7198	7198	7660	7660	6943	6943
Concrete (m ³)	1756	1756	1631	1631	1852	1852	1748	1748	1674	1674	1554	1554
Steel 8-12 mm (t)	63	62	61	61	98.3	98	97	98.7	94	94.1	93	93.1
Steel 12-50 mm (t)	86	83	80	78.3	90	85	87.3	85	79	74	76	72.6

Table 4.10. Analysis results and materials quantities for 24 Classroom's school buildings that applied in the second type of soil – Z2

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone												
T x (s)	0.28	0.28	0.38	0.38	0.34	0.34	0.43	0.43	0.33	0.33	0.48	0.48
T y (s)	0.33	0.33	0.42	0.42	0.43	0.43	0.51	0.51	0.43	0.43	0.59	0.59
W (t)	5054.28	5054.28	4850.55	4850.55	5229.83	5229.83	5022.88	5022.88	5192.97	5192.97	5035.59	5035.59
Vt x (t)	766.65	574.99	561.64	280.82	771.01	578.26	456.57	228.28	791.00	593.25	514.97	257.49
Vt y (t)	766.65	574.99	549.76	274.88	741.10	555.82	422.06	211.03	756.71	567.53	461.26	230.69
α s in x dir (diaphragm 1)	0.86	0.86	0.77	0.77	0.86	0.86	0.79	0.79	0.89	0.89	0.83	0.83
α s in y dir (diaphragm 1)	0.75	0.75	0.50	0.50	0.82	0.82	0.60	0.60	0.83	0.83	0.61	0.61
R (diaphragm 1)	6.56	6.56	5.5	5.5	6.73	6.73	4.75	4.75	6.44	6.44	5.83	5.83
α s in x dir (diaphragm 1)	0.69	0.69	.....	.....	0.64	0.64	.....	.....	0.73	0.73	....	....
α s in y dir (diaphragm 1)	0.64	0.64	.....	.....	0.71	0.71	.....	.....	0.76	0.76	.....	.....
R (diaphragm 1)	7	7	4	4	6.9	6.9	4	4	6.96	6.96	4	4
Formwork (m ²)	8703	8703	8068	8067	7737	7737	7199	7199	7662	7662	6946	6946
Concrete (m ³)	1785	1785	1665	1665	1899	1899	1778	1778	1706	1706	1589	1589
Steel 8-12 mm (t)	63	63	61	61	99	98	99	98.7	94	94.1	94	93.1
Steel 12-50 mm (t)	86	81	82	78	92	85	88	84	87	77	78	72.6

Table 4.11. Analysis results and materials quantities for 24 Classroom's school buildings that applied in the third type of soil – Z3

Type of F.S	Solid flooring system					Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z		1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone													
T x (s)	0.28	0.28	0.38	0.38		0.34	0.34	0.43	0.43	0.33	0.33	0.48	0.48
T y (s)	0.33	0.33	0.42	0.42		0.43	0.43	0.51	0.51	0.43	0.43	0.59	0.59
W (t)	5054.28	5054.28	4850.55	4850.55		5229.83	5229.83	5022.88	5022.88	5192.97	5192.97	5035.59	5035.59
Vt x (t)	766.65	574.99	561.64	280.82		771.01	578.26	479.71	239.85	791.00	593.25	572.34	286.17
Vt y (t)	766.65	574.99	561.64	280.82		771.01	578.26	479.71	239.85	791.00	593.25	572.34	286.17
α s in x dir (diaphragm 1)	0.86	0.86	0.77	0.77		0.86	0.86	0.79	0.79	0.89	0.89	0.83	0.83
α s in y dir (diaphragm 1)	0.75	0.75	0.50	0.50		0.82	0.82	0.60	0.60	0.83	0.83	0.61	0.61
R (diaphragm 1)	6.56	6.56	5.5	5.5		6.73	6.73	4.75	4.75	6.44	6.44	5.83	5.83
α s in x dir (diaphragm 1)	0.69	0.69	.....	.....		0.64	0.64	.....	.....	0.73	0.73	....	....
α s in y dir (diaphragm 1)	0.64	0.64	.....	.....		0.71	0.71	.....	.....	0.76	0.76	.....	.....
R (diaphragm 1)	7	7	4	4		6.9	6.9	4	4	6.96	6.96	4	4
Formwork (m ²)	8704	8704	8069	8067		7738	7738	7198	7198	7663	7663	6945	6946
Concrete (m ³)	1796	1796	1693	1693		1906	1906	1804	1804	1727	1727	1618	1617
Steel 8-12 mm (t)	63	63	61	61		99	98	99	98.7	98.1	94.1	92.6	93
Steel 12-50 mm (t)	87	83	83	77.8		92	87	89	84	86	78	83.3	74

Table 4.12. Analysis results and materials quantities for 24 Classroom's school buildings that applied in the fourth type of soil – Z4

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone												
T x (s)	0.28	0.28	0.38	0.38	0.34	0.34	0.43	0.43	0.33	0.33	0.48	0.48
T y (s)	0.33	0.33	0.42	0.42	0.43	0.43	0.51	0.51	0.43	0.43	0.59	0.59
W (t)	5054.28	5054.28	4850.55	4850.55	5229.83	5229.83	5022.88	5022.88	5192.97	5192.97	5035.59	5035.59
Vt x (t)	766.65	574.99	561.64	280.82	771.01	578.26	479.71	239.85	791.00	593.25	572.34	286.17
Vt y (t)	766.65	574.99	561.64	280.82	771.01	578.26	479.71	239.85	791.00	593.25	572.34	286.17
α s in x dir (diaphragm 1)	0.86	0.86	0.77	0.77	0.86	0.86	0.79	0.79	0.89	0.89	0.83	0.83
α s in y dir (diaphragm 1)	0.75	0.75	0.50	0.50	0.82	0.82	0.60	0.60	0.83	0.83	0.61	0.61
R (diaphragm 1)	6.56	6.56	5.5	5.5	6.73	6.73	4.75	4.75	6.44	6.44	5.83	5.83
α s in x dir (diaphragm 1)	0.69	0.69	.....	.....	0.64	0.64	.....	.....	0.73	0.73	....	....
α s in y dir (diaphragm 1)	0.64	0.64	.....	.....	0.71	0.71	.....	.....	0.76	0.76	.....	.....
R (diaphragm 1)	7	7	4	4	6.9	6.9	4	4	6.96	6.96	4	4
Formwork (m ²)	8707	8707	8068	8068	7740	7740	7200	7200	7666	7666	6946	6946
Concrete (m ³)	1867	1867	1722	1722	1960	1960	1843	1843	1776	1776	1650	1650
Steel 8-12 mm (t)	63	63	61.1	61.4	99	98	99	99	94	94.1	92.9	93
Steel 12-50 mm (t)	89	84	84	79.8	96	90	92	87	86	78.5	85.9	76

Table 4.13. Analysis results and materials quantities for 32 Classroom's school buildings that applied in the first type of soil – Z1

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone												
T x (s)	0.37	0.37	0.46	0.46	0.45	0.45	0.60	0.60	0.46	0.46	0.63	0.63
T y (s)	0.43	0.43	0.52	0.52	0.60	0.60	0.77	0.77	0.58	0.58	0.73	0.73
W (t)	6212.29	6212.29	5966.13	5966.13	6397.16	6397.16	6115.35	6115.35	6361.34	6361.34	6160.73	6160.73
Vt x (t)	876.03	657.02	554.87	277.44	771.99	578.99	418.33	209.16	787.30	590.48	462.54	231.27
Vt y (t)	764.94	573.70	496.01	248.00	606.65	454.99	322.78	161.39	637.98	478.48	393.81	196.91
α s in x dir (diaphragm 1)	0.83	0.83	0.73	0.73	0.85	0.85	0.76	0.76	0.88	0.88	0.81	0.81
α s in y dir (diaphragm 1)	0.73	0.73	0.50	0.50	0.80	0.80	0.58	0.58	0.81	0.81	0.57	0.57
R (diaphragm 1)	6.68	6.68	5.5	5.5	6.6	6.6	4.71	4.71	6.48	6.48	5.74	5.74
α s in x dir (diaphragm 1)	0.65	0.65	.....	.....	0.62	0.62	.....	.....	0.67	0.67	.....	.....
α s in y dir (diaphragm 1)	0.62	0.62	.....	.....	0.70	0.70	.....	.....	0.73	0.73	.....	.....
R (diaphragm 1)	7	7	4	4	6.95	6.95	4	4	7	7	4	4
Formwork (m ²)	10552	10551	9736	9735	9285	9283	8521	8520	9245	9244	8405	8405
Concrete (m ³)	2086	2077	1948	1947	2186	2174	2057	2057	1981	1972	1863.1	1863
Steel 8-12 mm (t)	78	77	76	76.4	111	111	112	112	117	116.4	116	115
Steel 12-50 mm (t)	103	98	98.2	93	105	99	102	99.4	95	87	91	87.2

Table 4.14. Analysis results and materials quantities for 32 Classroom's school buildings that applied in the second type of soil – Z2

Type of F.S	Solid flooring system					Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z		1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone													
T x (s)	0.37	0.37	0.46	0.46		0.45	0.45	0.60	0.60	0.46	0.46	0.63	0.63
T y (s)	0.43	0.43	0.52	0.52		0.60	0.60	0.77	0.77	0.58	0.58	0.73	0.73
W (t)	6212.29	6212.29	5966.13	5966.13		6397.16	6397.16	6115.35	6115.35	6361.34	6361.34	6160.73	6160.73
Vt x (t)	972.92	729.69	665.22	332.61		926.23	694.67	519.08	259.54	940.18	705.14	574.67	287.34
Vt y (t)	936.47	702.36	621.74	310.87		763.65	572.37	406.31	203.16	803.07	602.30	496.62	248.31
α s in x dir (diaphragm 1)	0.83	0.83	0.73	0.73		0.85	0.85	0.76	0.76	0.88	0.88	0.81	0.81
α s in y dir (diaphragm 1)	0.73	0.73	0.50	0.50		0.80	0.80	0.58	0.58	0.81	0.81	0.57	0.57
R (diaphragm 1)	6.68	6.68	5.5	5.5		6.8	6.6	4.71	4.71	6.48	6.48	5.74	5.71
α s in x dir (diaphragm 1)	0.65	0.65	.....	.....		0.62	0.62	.....	.....	0.67	0.67	.....	.....
α s in y dir (diaphragm 1)	0.62	0.62	.....	.....		0.70	0.70	.....	.....	0.73	0.73	.....	.....
R (diaphragm 1)	7	7	4	4		6.95	6.95	4	4	7	7	4	4
Formwork (m ²)	10553	10552	9737	9737		9286	9286	8522	8522	9247	9246	8407	8407
Concrete (m ³)	2125.3	2116.5	1983	1983		2243	2235.8	2108	2108	2022	2006	1903	1904
Steel 8-12 mm (t)	78	77	75.5	76.4		111	110.6	112	111.6	116	116.4	116.4	115.4
Steel 12-50 mm (t)	109.3	100.2	102	94		110.3	100.2	107.3	101.8	101	92	97	88

Table 4.15. Analysis results and materials quantities for 32 Classroom's school buildings that applied in the third type of soil – Z3

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone												
T x (s)	0.37	0.37	0.46	0.46	0.45	0.45	0.56	0.56	0.46	0.46	0.63	0.63
T y (s)	0.43	0.43	0.52	0.52	0.60	0.60	0.77	0.77	0.58	0.58	0.73	0.73
W (t)	6212.29	6212.29	5966.13	5966.13	6397.16	6397.16	6115.35	6115.35	6361.34	6361.34	6160.73	6160.73
Vt x (t)	972.92	729.69	721.19	360.59	982.86	737.14	615.01	307.50	1002.20	751.65	715.33	357.67
Vt y (t)	972.92	729.69	721.19	360.59	982.86	737.14	542.01	371.05	1002.20	751.65	658.33	329.17
α s in x dir (diaphragm 1)	0.83	0.83	0.73	0.73	0.85	0.85	0.76	0.76	0.88	0.88	0.81	0.81
α s in y dir (diaphragm 1)	0.73	0.73	0.50	0.50	0.80	0.80	0.58	0.58	0.81	0.81	0.57	0.57
R (diaphragm 1)	6.68	6.68	5.5	5.5	6.8	6.6	4.71	4.71	6.48	6.48	5.74	5.71
α s in x dir (diaphragm 1)	0.65	0.65	.....	.....	0.62	0.62	.....	.....	0.67	0.67	.....	.....
α s in y dir (diaphragm 1)	0.62	0.62	.....	.....	0.70	0.70	.....	.....	0.73	0.73	.....	.....
R (diaphragm 1)	7	7	4	4	6.95	6.95	4	4	7	7	4	4
Formwork (m ²)	10554	10553	9738	9739	9287	9286	8523	8523	9248	9246	8408	8408
Concrete (m ³)	2137	2122.3	1994.5	1995	2258	2235	2122	2122	2049	2023.2	1918	1919
Steel 8-12 mm (t)	78	77	75.5	76.4	111	110.6	113	111.6	115	117.4	116.4	115.4
Steel 12-50 mm (t)	111.6	103.2	106	96.4	127.9	110.2	110	102.8	118	98	107	91.1

Table 4.16. Analysis results and materials quantities for 32 Classroom's school buildings that applied in the fourth type of soil – Z4

Type of F.S	Solid flooring system				Flat flooring system				Ribbed flooring system			
	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z	1 st S.Z	2 nd S.Z	3 rd S.Z	4 th S.Z
Type of seismic zone												
T x (s)	0.37	0.37	0.46	0.46	0.45	0.45	0.56	0.56	0.46	0.46	0.63	0.63
T y (s)	0.43	0.43	0.52	0.52	0.60	0.60	0.77	0.77	0.58	0.58	0.73	0.73
W (t)	6212.29	6212.29	5966.13	5966.13	6397.16	6397.16	6115.35	6115.35	6361.34	6361.34	6160.73	6160.73
Vt x (t)	972.92	729.69	721.19	360.59	982.86	737.14	615.01	307.50	1002.20	751.65	715.33	357.67
Vt y (t)	972.92	729.69	721.19	360.59	982.86	737.14	615.01	307.50	1002.20	751.65	658.33	329.17
α s in x dir (diaphragm 1)	0.83	0.83	0.73	0.73	0.85	0.85	0.76	0.76	0.88	0.88	0.81	0.81
α s in y dir (diaphragm 1)	0.73	0.73	0.50	0.50	0.80	0.80	0.58	0.58	0.81	0.81	0.57	0.57
R (diaphragm 1)	6.68	6.68	5.5	5.5	6.8	6.6	4.71	4.71	6.48	6.48	5.74	5.71
α s in x dir (diaphragm 1)	0.65	0.65	.....	.....	0.62	0.62	.....	.....	0.67	0.67	.....	.....
α s in y dir (diaphragm 1)	0.62	0.62	.....	.....	0.70	0.70	.....	.....	0.73	0.73	.....	.....
R (diaphragm 1)	7	7	4	4	6.95	6.95	4	4	7	7	4	4
Formwork (m ²)	10556	10556	9739.5	9741	9290	9288	8526	8526	9250	9249	8411	8411
Concrete (m ³)	2221	2189	2052	2052	2328	2312	2178	2179	2118	2104	1975	1975
Steel 8-12 mm (t)	78	77	74.5	76.4	110	110.9	112.6	112	115.6	117.4	115.8	115.8
Steel 12-50 mm (t)	111.6	102.2	105	92.4	127.9	107.2	111	101	115.8	99	106	92

The goal of this study is to know the economic cost of the schools buildings , so the results of quantities of structural materials must be presented clearly. So the quantities of concrete, formwork, and steel for all models will be displayed as a charts in the following figures.

1. Quantities of formwork, concrete, and steel for 8 classroom's school buildings

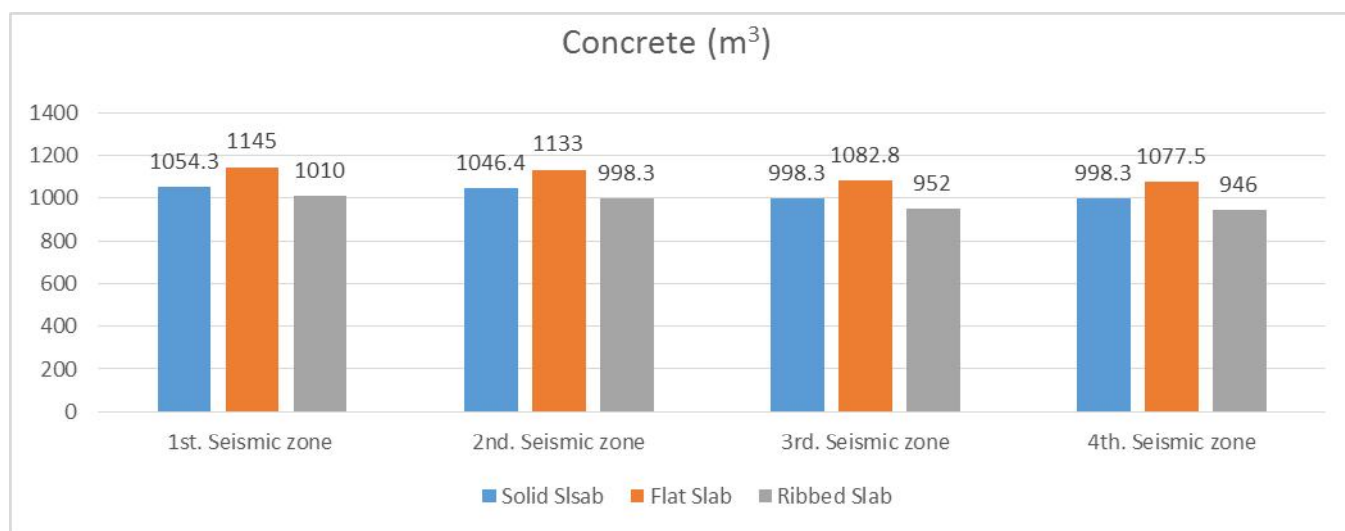


Figure 4.1. Quantities of concrete in 8 classroom's school for the first type of soil (Z1)

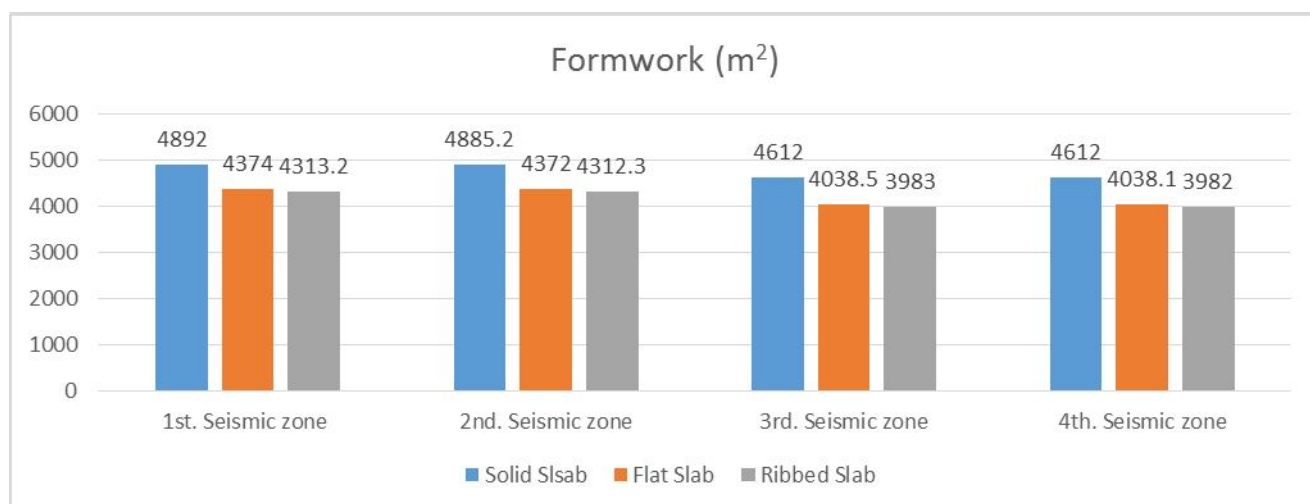


Figure 4.2. Quantities of formwork in 8 classroom school for the first type of soil (Z1)

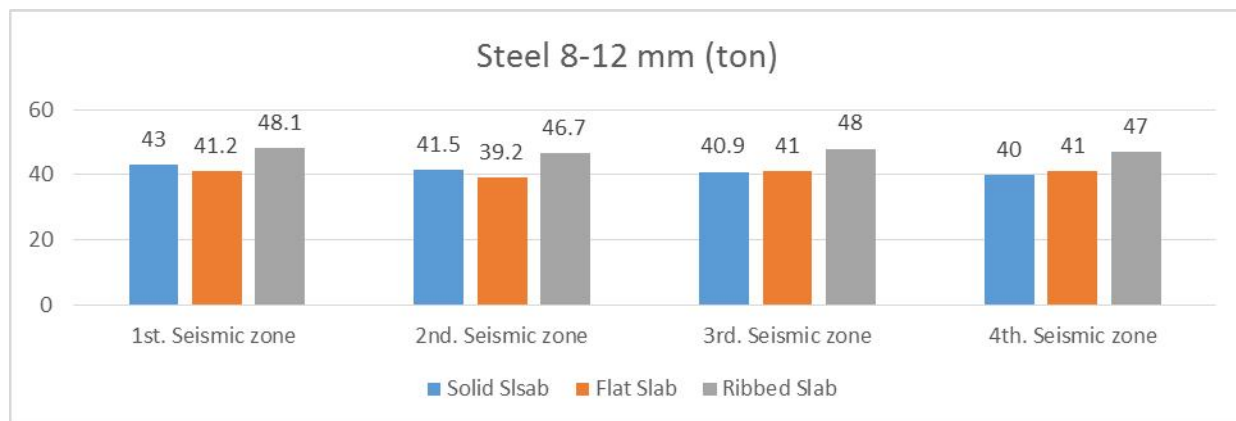


Figure 4.3. Quantities of steel (8-12mm) in 8 classroom school for the first type of soil (Z1)



Figure 4.4. Quantities of steel (14-50 mm) in 8 classroom school for the first type of soil (Z1)

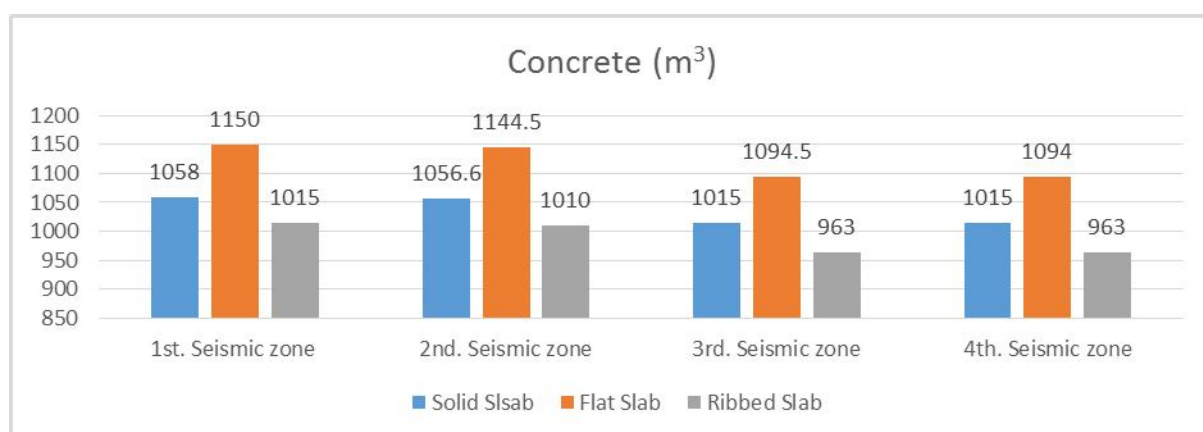


Figure 4.5. Quantities of concrete in 8 classroom's school for the second type of soil (Z2)

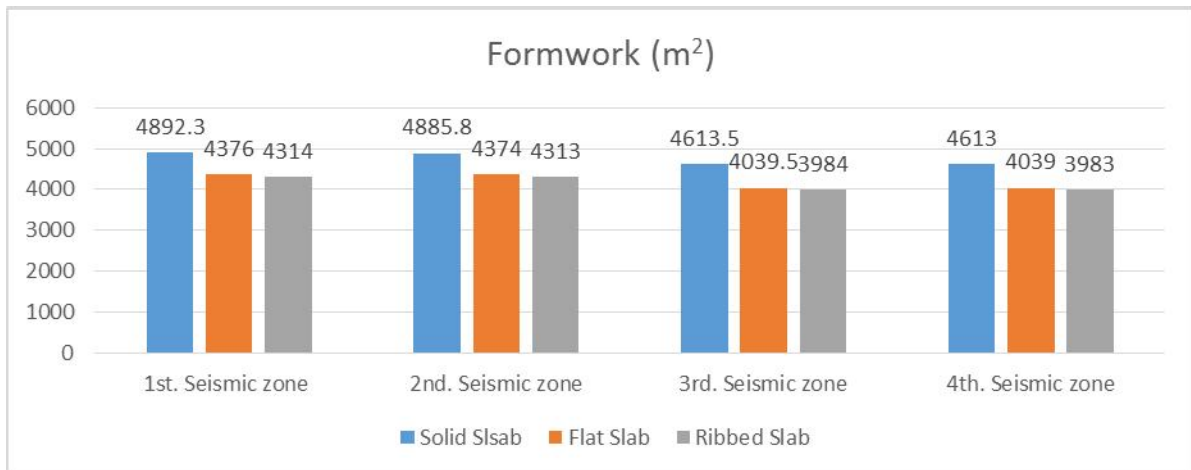


Figure 4.6. Quantities of formwork in 8 classroom's school for the second type of soil (Z2)

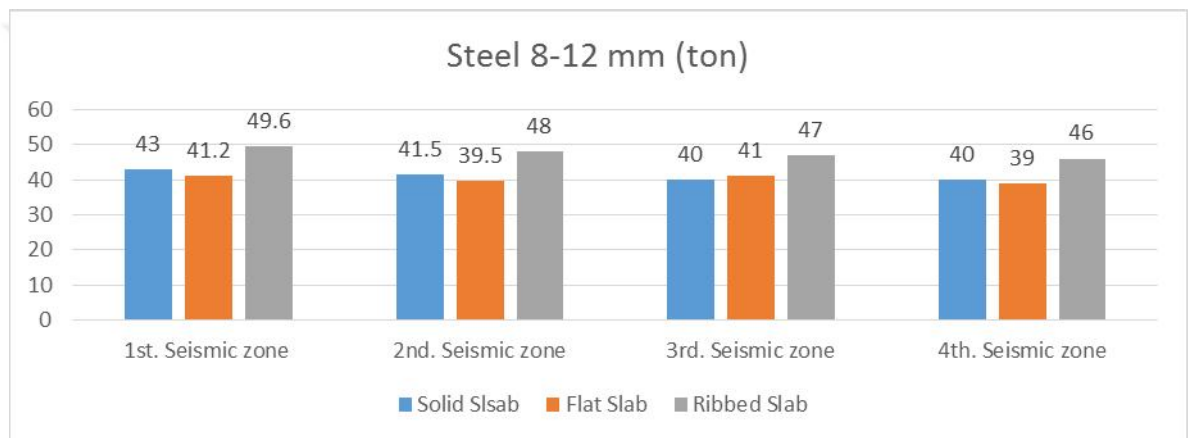


Figure 4.7. Quantities of steel (8-12mm) in 8 classroom's school for the second type of soil (Z2)

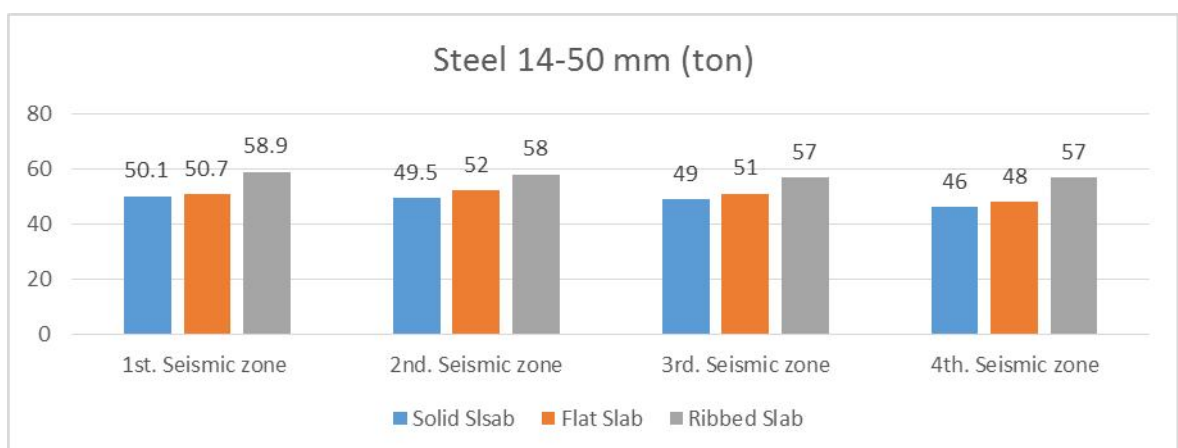


Figure 4.8. Quantities of steel (14-50mm) in 8 classroom's school for the second type of soil (Z2)

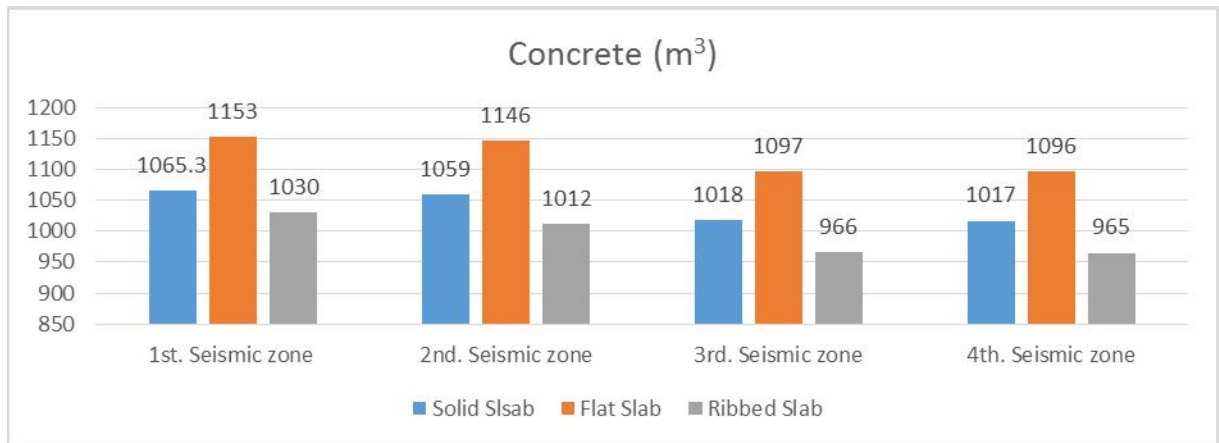


Figure 4.9. Quantities of concrete in 8 classroom's school for the third type of soil (Z3)

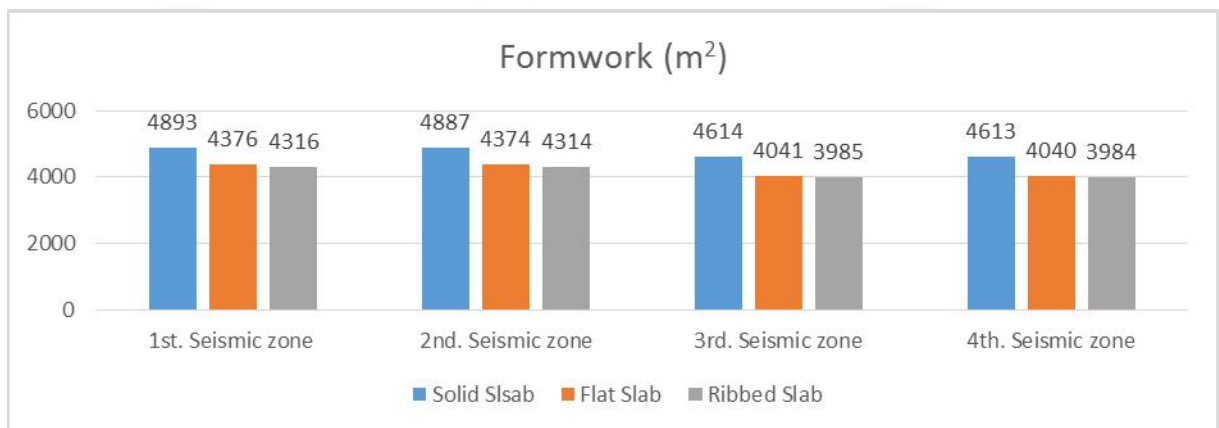


Figure 4.10. Quantities of formwork in 8 classroom's school for the third type of soil (Z3)

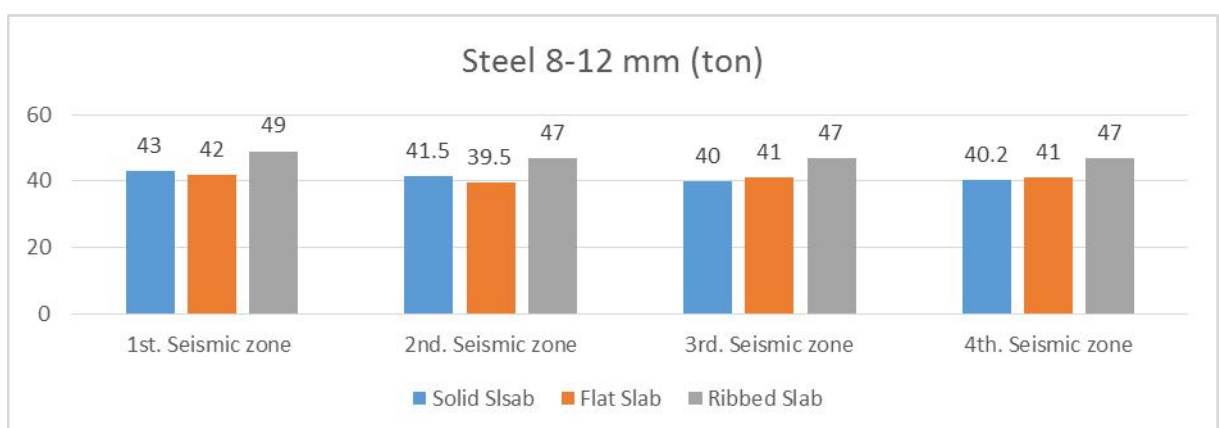


Figure 4.11. Quantities of steel (8-12mm) in 8 classroom's school for the third type of soil (Z3)



Figure 4.12. Quantities of steel (14-50mm) in 8 classroom's school for the third type of soil (Z3)

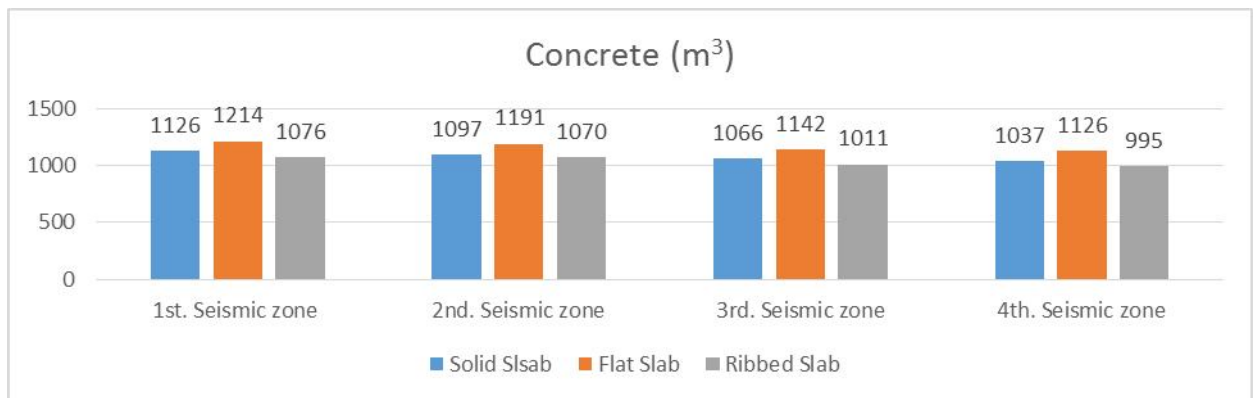


Figure 4.13. Quantities of concrete in 8 classroom's school for the fourth type of soil (Z4)

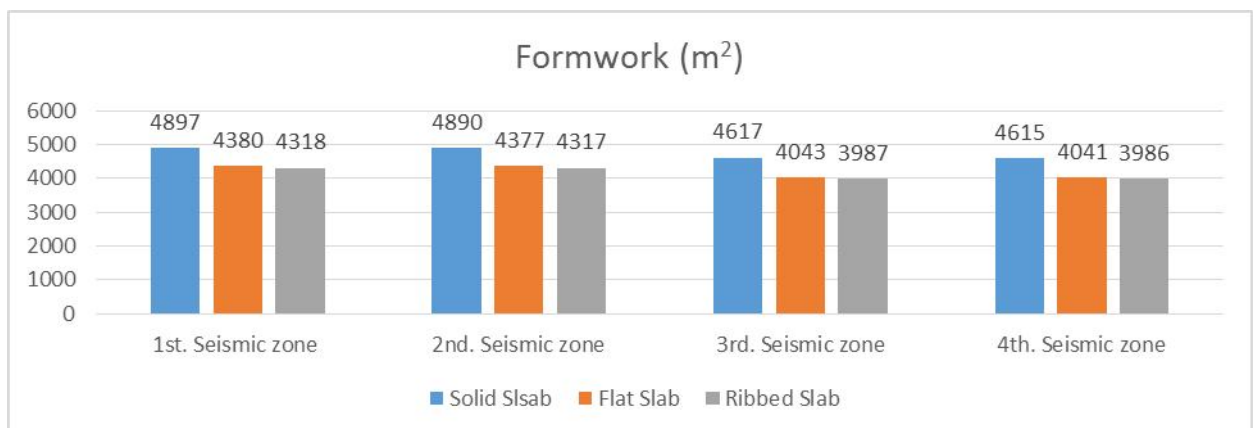


Figure 4.14. Quantities of formwork in 8 classroom's school for the fourth type of soil (Z4)



Figure 4.15. Quantities of steel (8-12mm) in 8 classroom's school for the fourth type of soil (Z4)



Figure 4.16. Quantities of steel (14-50) in 8 classroom's school for the fourth type of soil (Z4)

2. Quantities of formwork, concrete, and steel for 16 classroom's school buildings

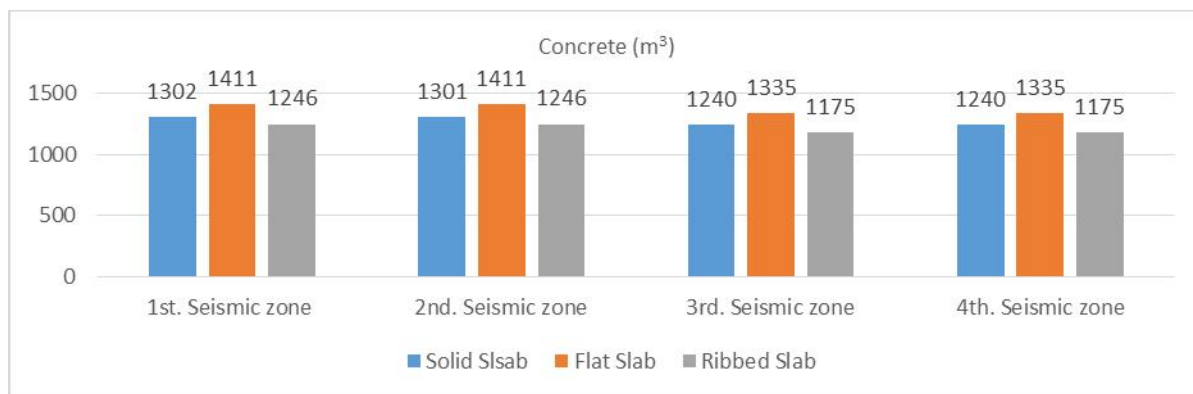


Figure 4.17. Quantities of concrete in 16 classroom's school for the first type of soil (Z1)

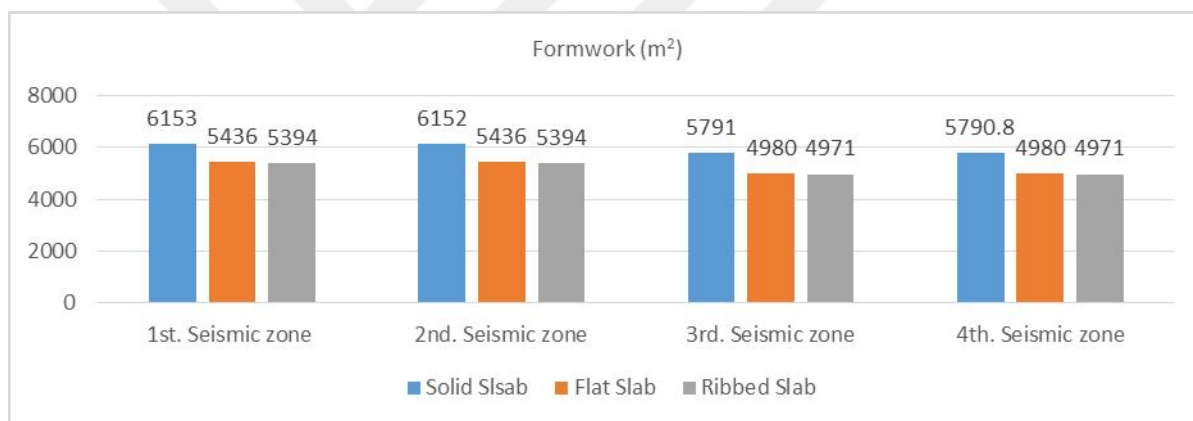


Figure 4.18. Quantities of formwork in 16 classroom's school for the first type of soil (Z1)

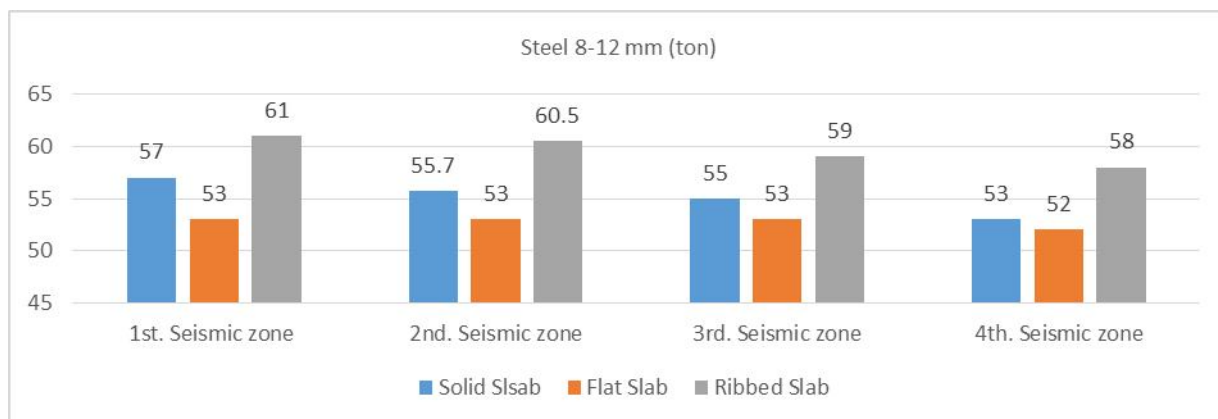


Figure 4.19. Quantities of steel (8-12mm) in 16 classroom's school for the first type of soil (Z1)

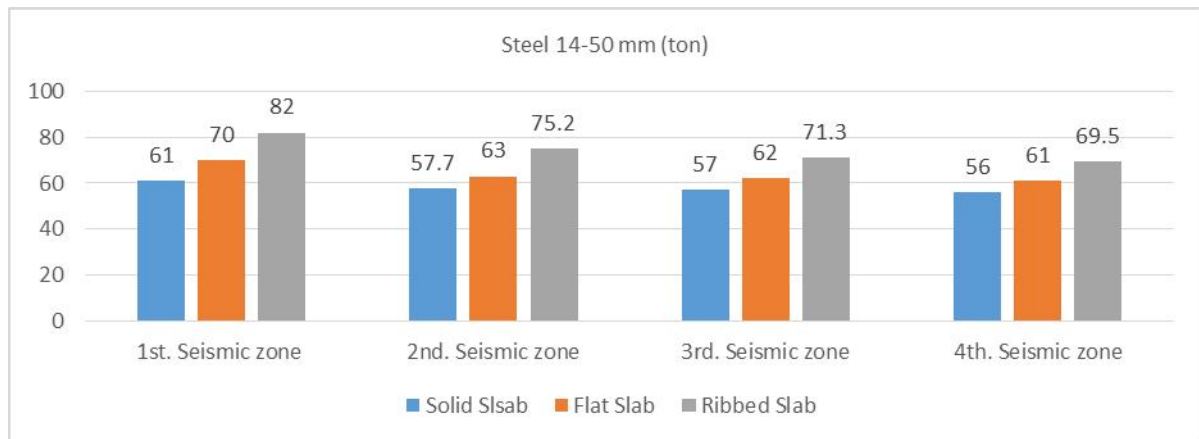


Figure 4.20. Quantities of steel (14-50mm) in 16 classroom's school for the first type of soil (Z1)



Figure 4.21. Quantities of concrete in 16 classroom's school for the second type of soil (Z2)

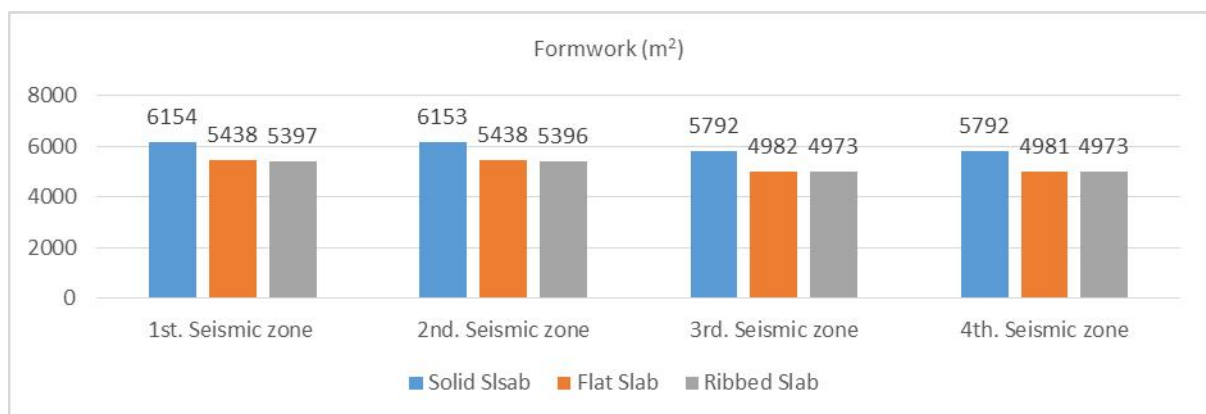


Figure 4.22. Quantities of formwork in 16 classroom's school for the second type of soil (Z2)

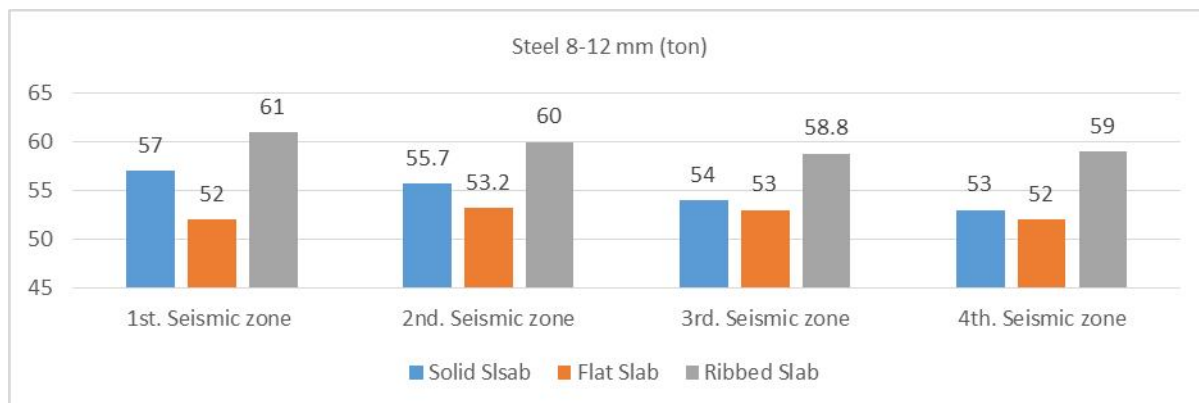


Figure 4.23. Quantities of steel (8-12mm) in 16 classroom's school for the second type of soil (Z2)

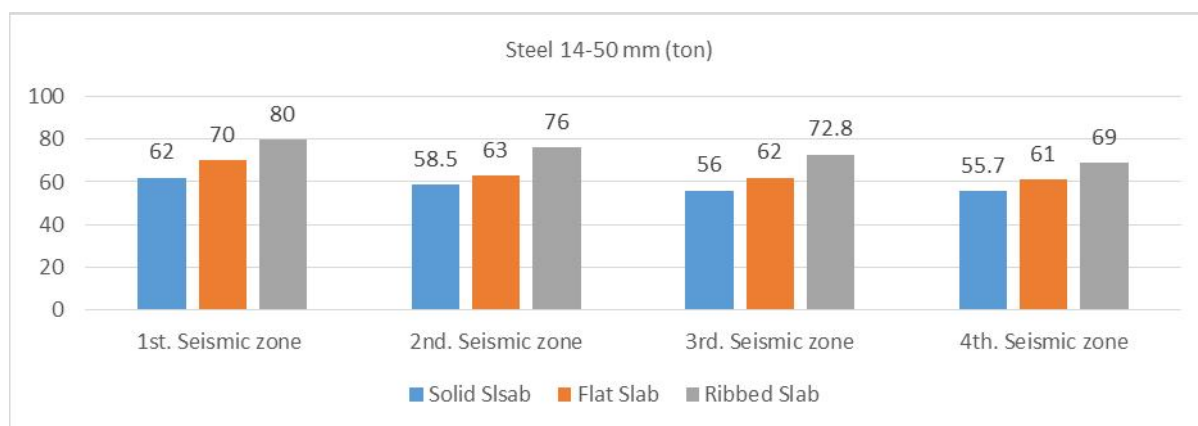


Figure 4.24. Quantities of steel (14-50mm) in 16 classroom's school for the second type of soil (Z2)

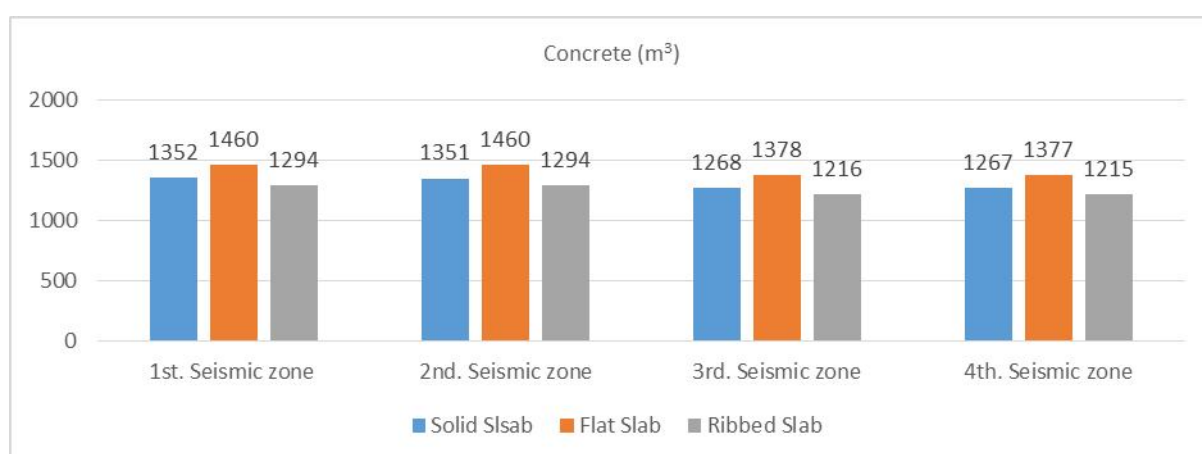


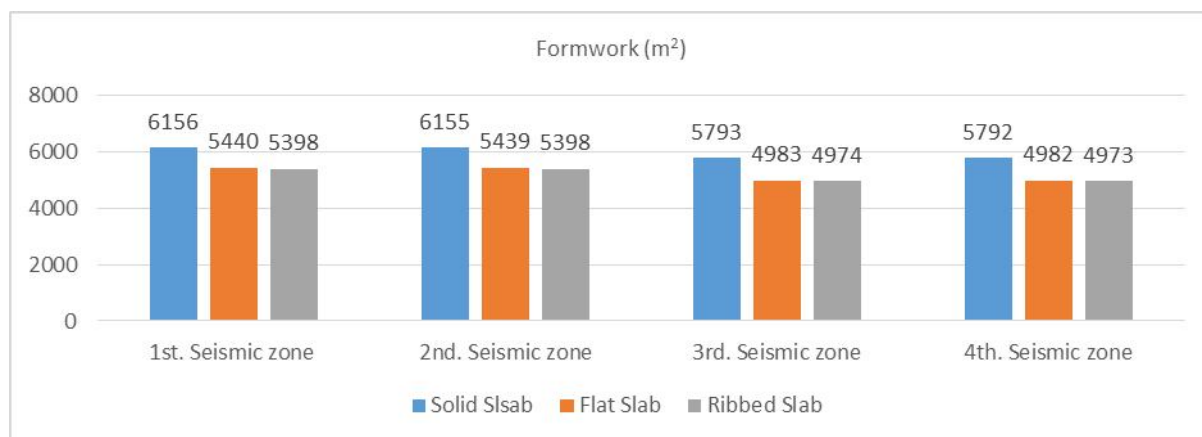
Figure 3.25. Quantities of concrete in 16 classroom's school for the third type of soil (Z3)**Figure 3.26.** Quantities of formwork in 16 classroom's school for the third type of soil (Z3)**Figure 4.27.** Quantities of steel (8-12mm) in 16 classroom's school for the third type of soil (Z3)**Figure 4.28.** Quantities of steel (14-50mm) in 16 classroom's school for the third type of soil (Z3)



Figure 4.29. Quantities of concrete in 16 classroom's school for the fourth type of soil (Z4)



Figure 4.30. Quantities of formwork in 16 classroom's school for the fourth type of soil (Z4)

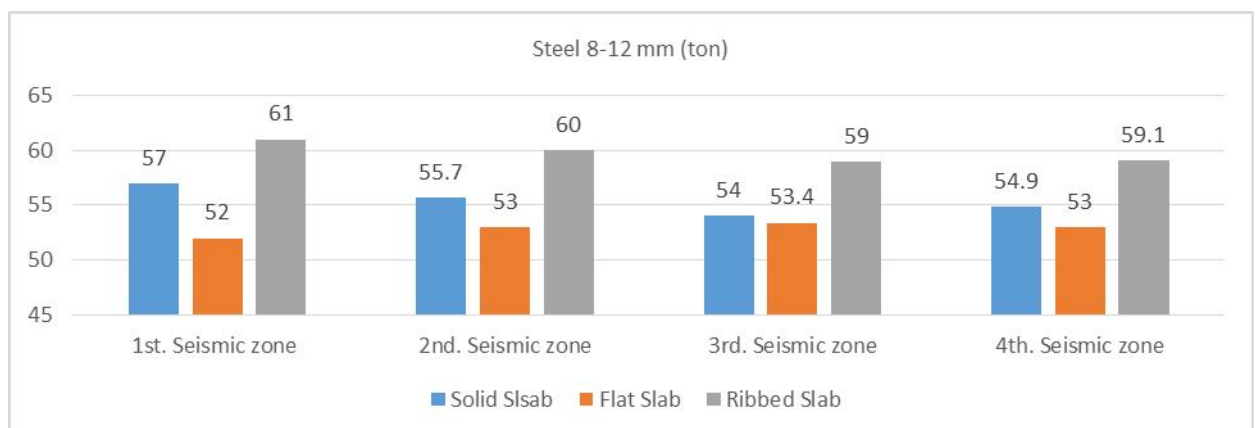


Figure 4.31. Quantities of steel (8-12mm) in 16 classroom's school for the fourth type of soil (Z4)

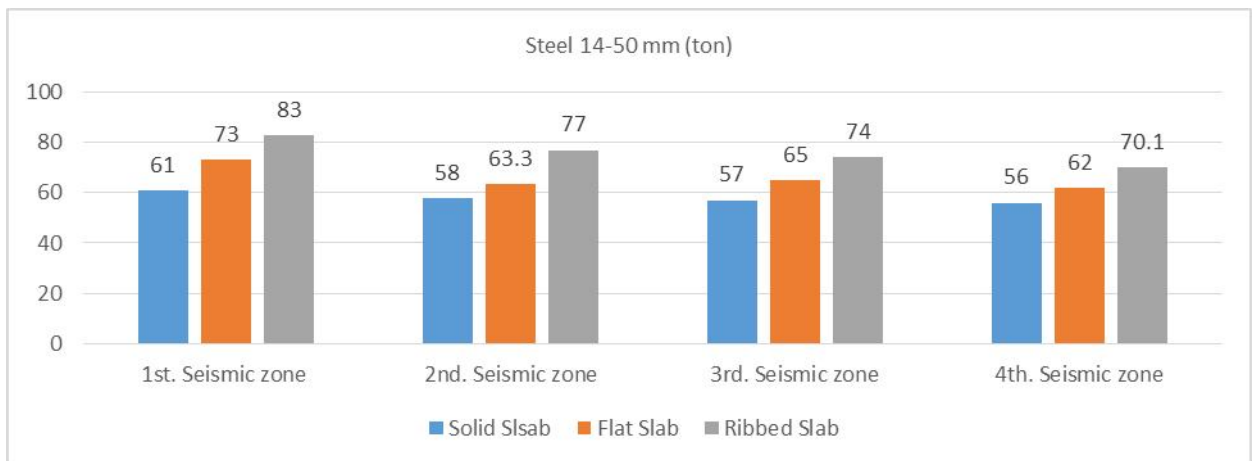


Figure 4.32. Quantities of steel (14-50mm) in 16 classroom's school for the fourth type of soil (Z4)

Quantities of formwork, concrete, and steel for 24 classroom's school buildings



Figure 4.33. Quantities of concrete in 24 classroom's school for the first type of soil (Z1)

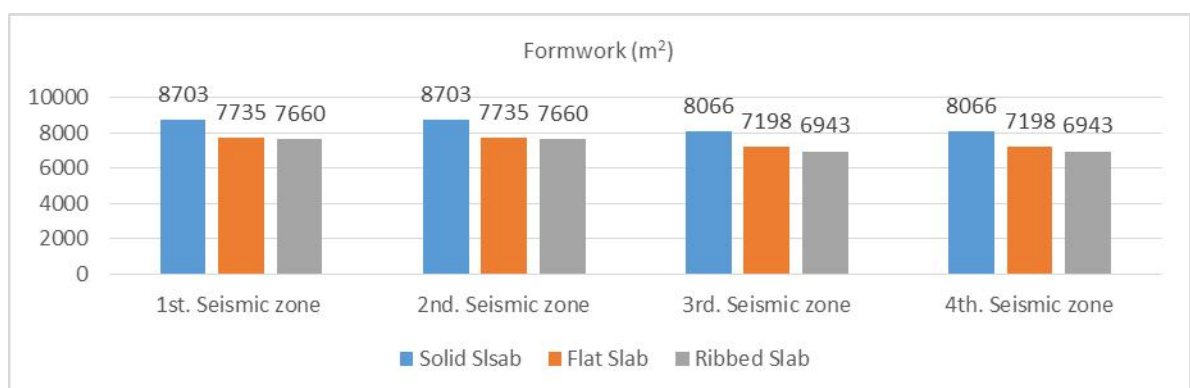


Figure 4.34. Quantities of formwork in 24 classroom's school for the first type of soil (Z1)

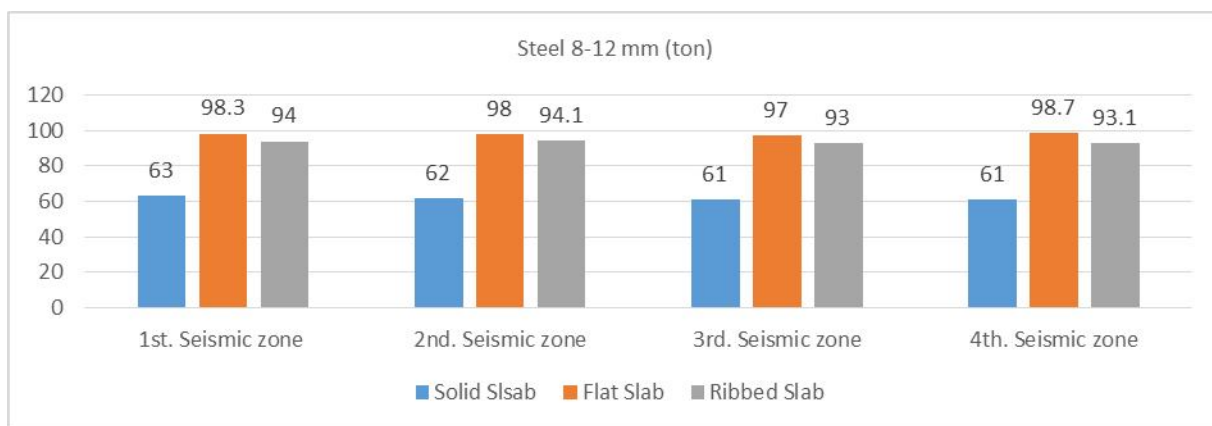


Figure 4.35. Quantities of steel (8-12mm) in 24 classroom's school for the first type of soil (Z1)

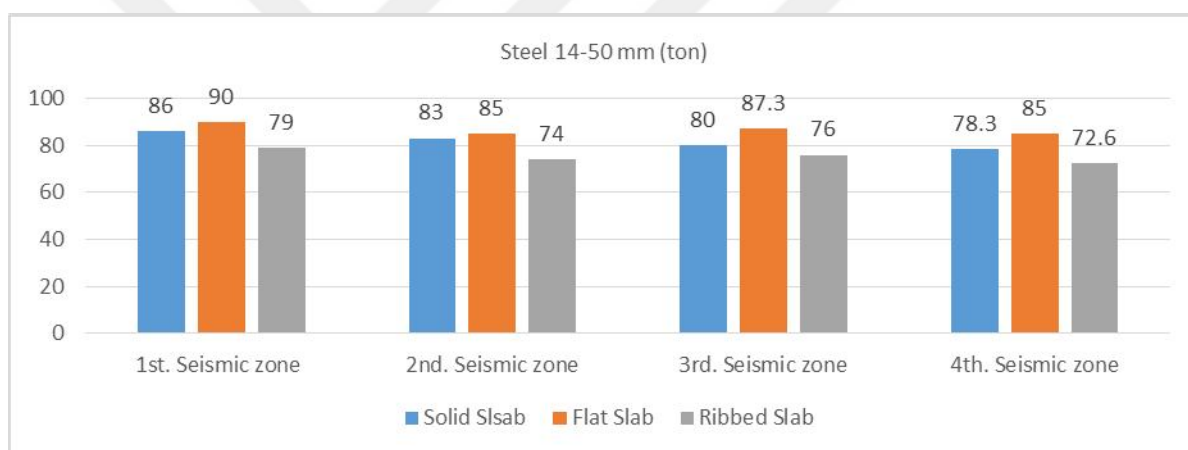


Figure 4.36. Quantities of steel (14-50mm) in 24 classroom's school for the first type of soil (Z1)

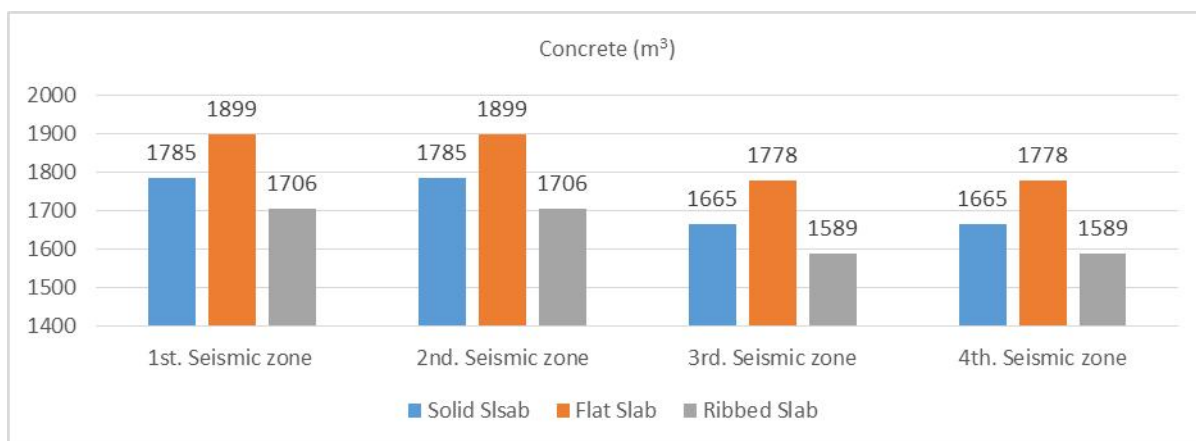


Figure 4.37. Quantities of concrete in 24 classroom's school for the second type of soil (Z2)

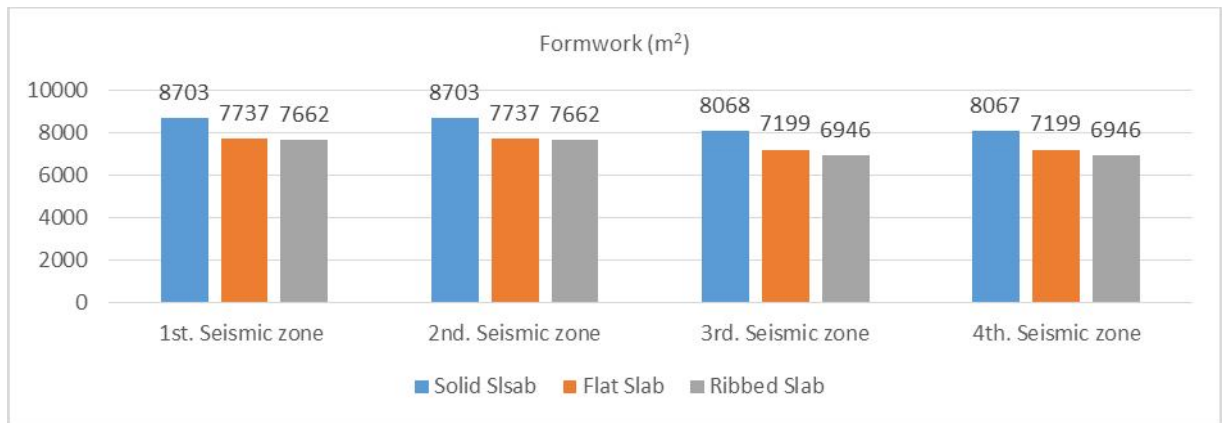


Figure 4.38. Quantities of formwork in 24 classroom's school for the second type of soil (Z2)



Figure 4.39. Quantities of steel (8-12mm) in 24 classroom's school for the second type of soil (Z2)

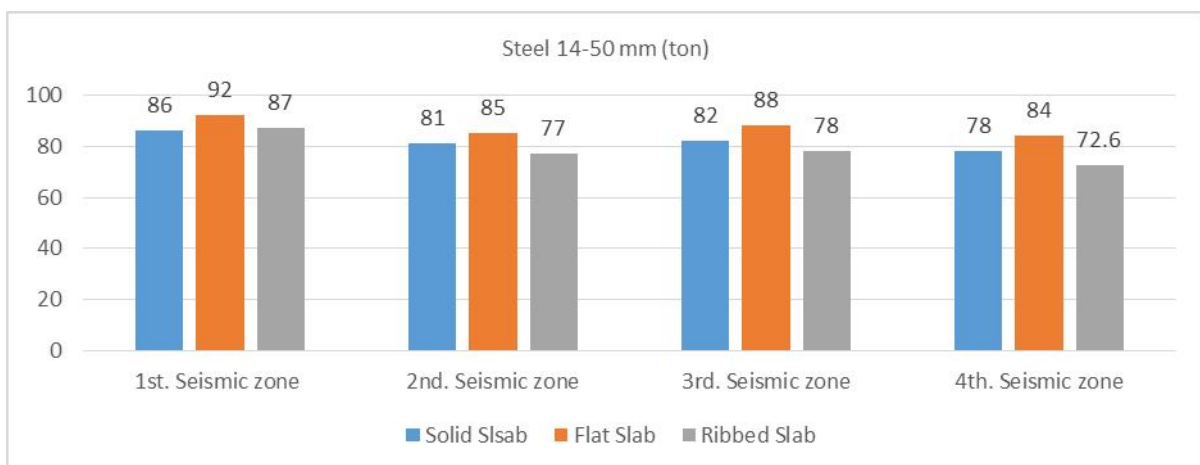


Figure 4.40. Quantities of steel (14-50 mm) in 24 classroom's school for the second type of soil (Z2)

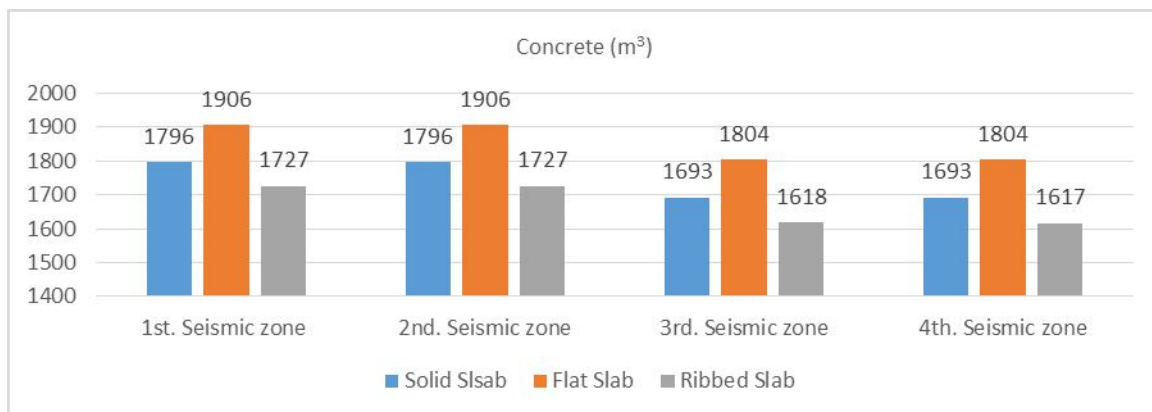


Figure 4.41. Quantities of concrete in 24 classroom's school for the third type of soil (Z3)



Figure 4.42. Quantities of formwork in 24 classroom's school for the third type of soil (Z3)

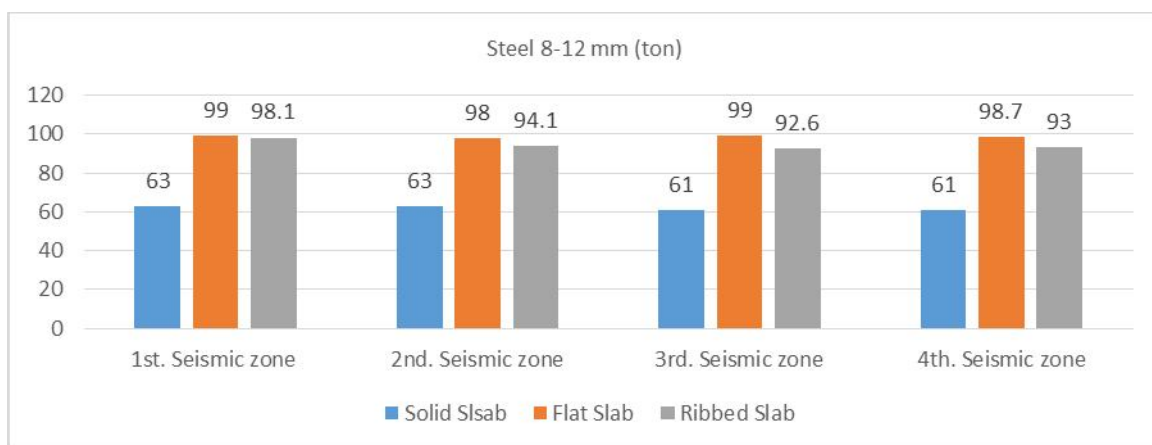


Figure 4.43. Quantities of steel (8-12 mm) in 24 classroom's school for the third type of soil (Z3)

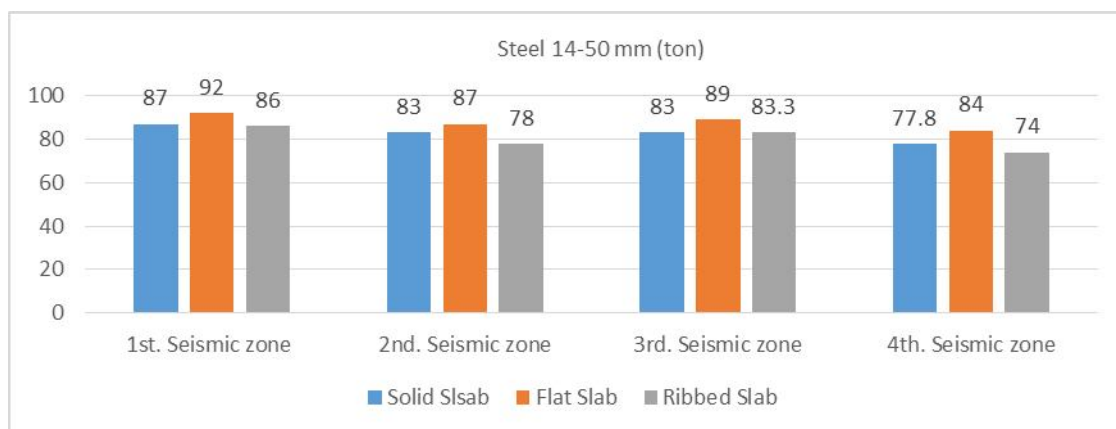


Figure 4.44. Quantities of steel (14-50 mm) in 24 classroom's school for the third type of soil (Z3)

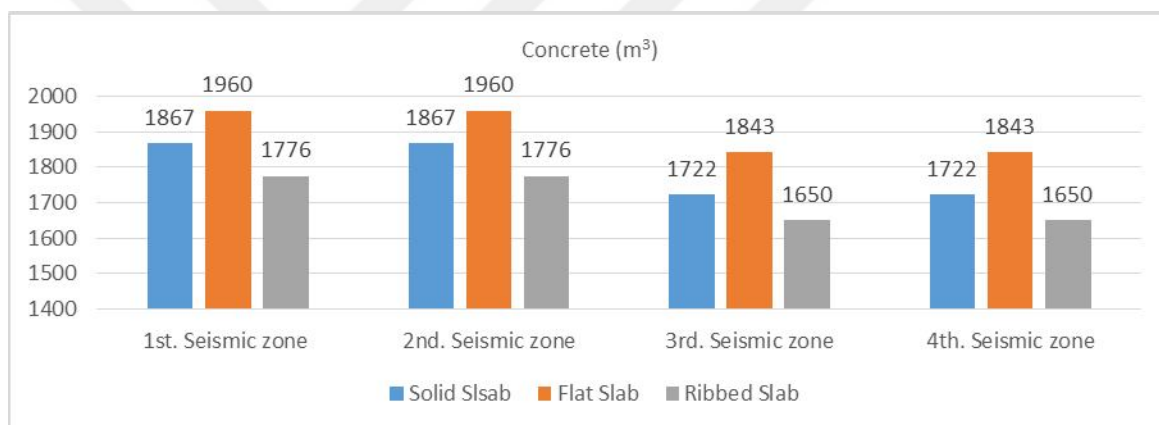


Figure 4.45. Quantities of concrete in 24 classroom's school for the fourth type of soil (Z4)

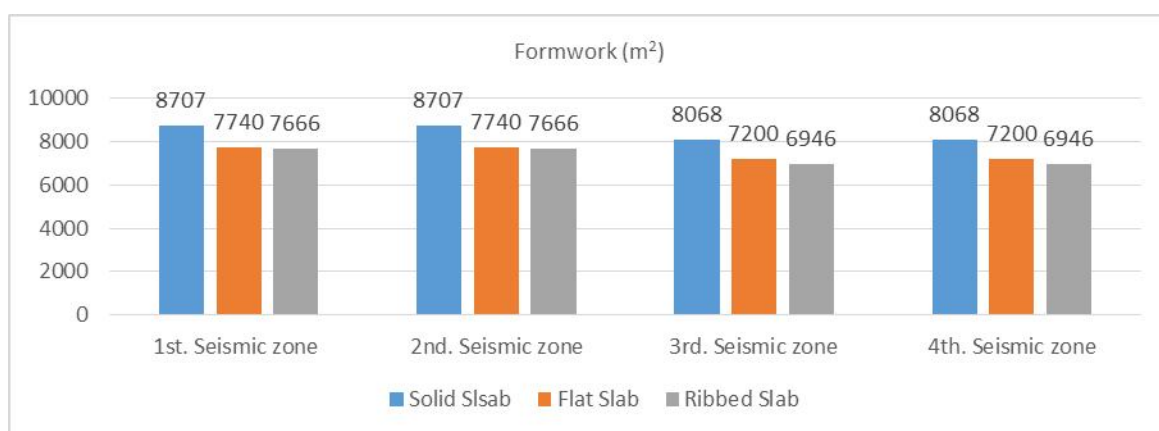


Figure 4.46. Quantities of formwork in 24 classroom's school for the fourth type of soil (Z4)



Figure 4.47. Quantities of steel (8-12 mm) in 24 classroom's school for the fourth type of soil (Z4)

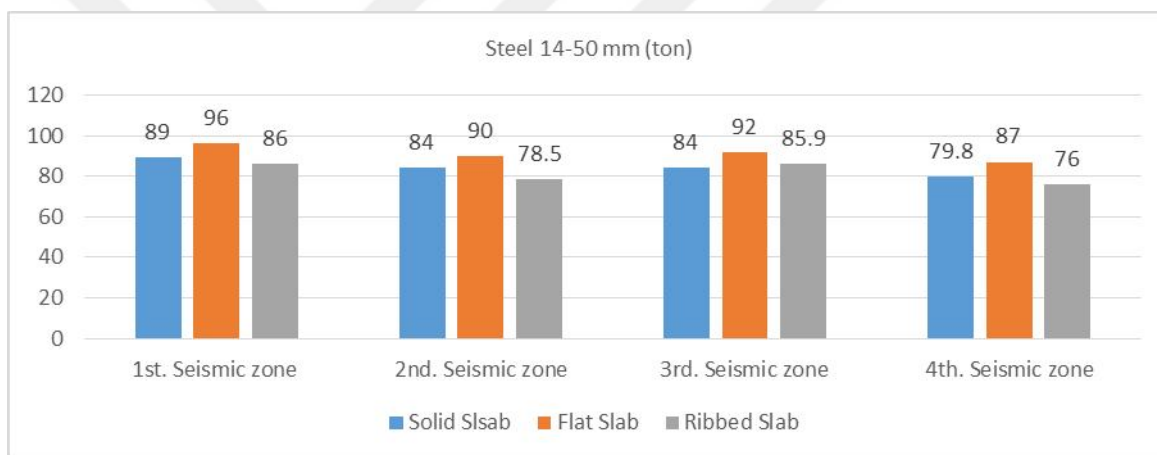


Figure 4.48. Quantities of steel (14-50 mm) in 24 classroom's school for the fourth type of soil (Z4)

4. Quantities of formwork, concrete, and steel for 32 classroom's school buildings

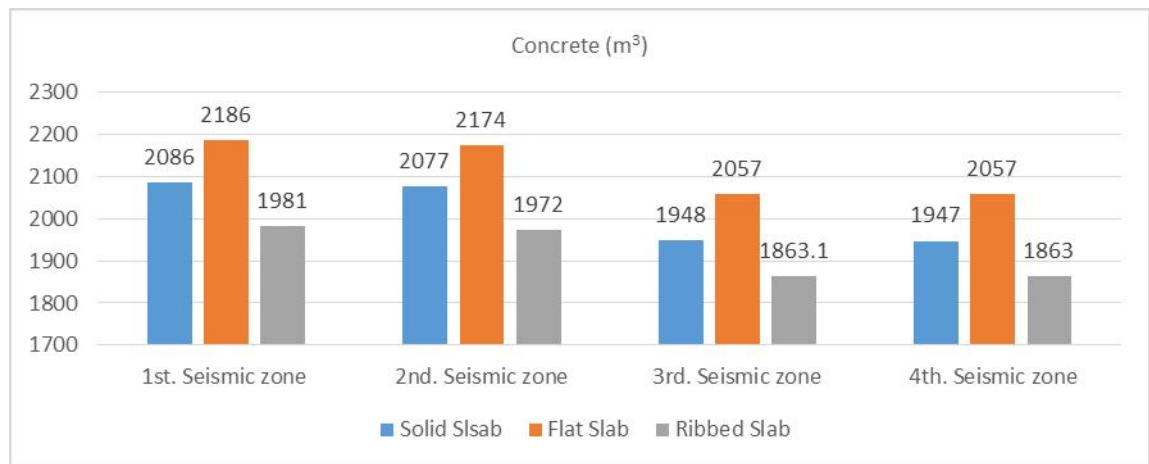


Figure 4.49. Quantities of concrete in 32 classroom's school for the first type of soil (Z1)

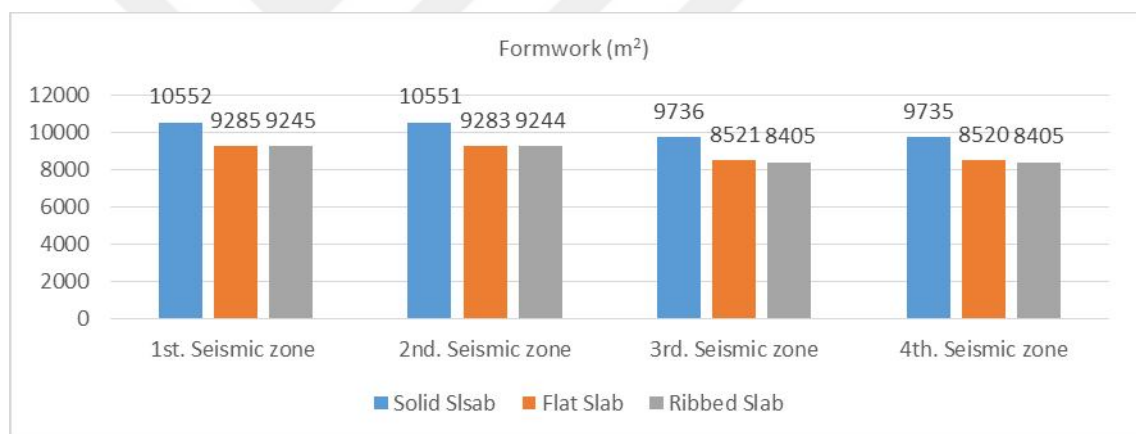


Figure 4.50. Quantities of formwork in 32 classroom's school for the first type of soil (Z1)

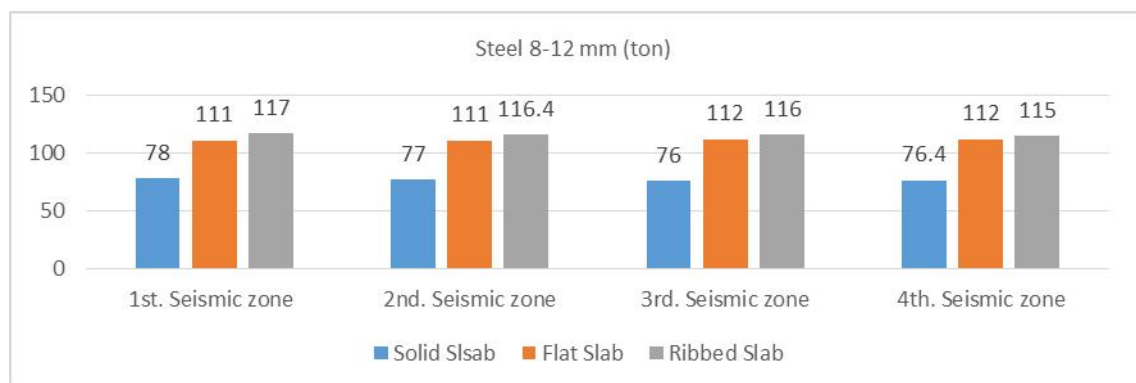


Figure 4.51. Quantities of steel (8-12 mm) in 32 classroom's school for the first type of soil (Z1)

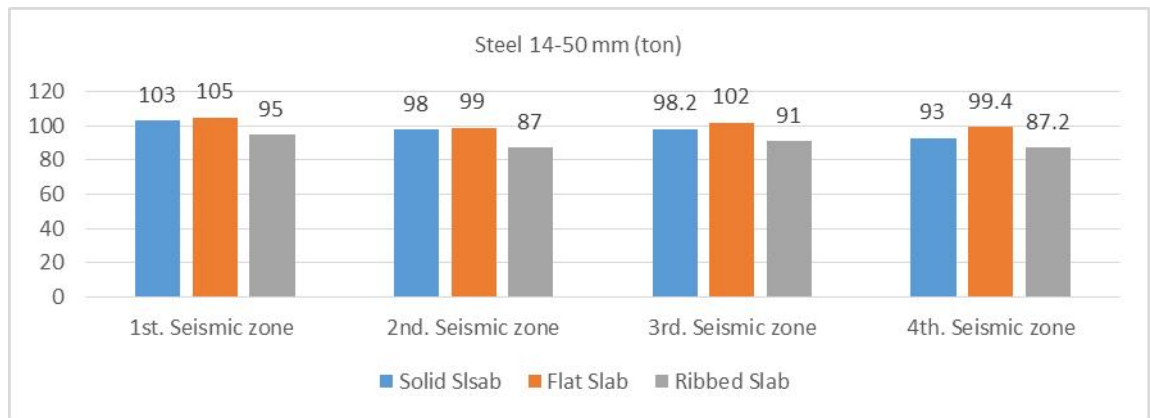


Figure 4.52. Quantities of steel (14-51 mm) in 32 classroom's school for the first type of soil (Z1)

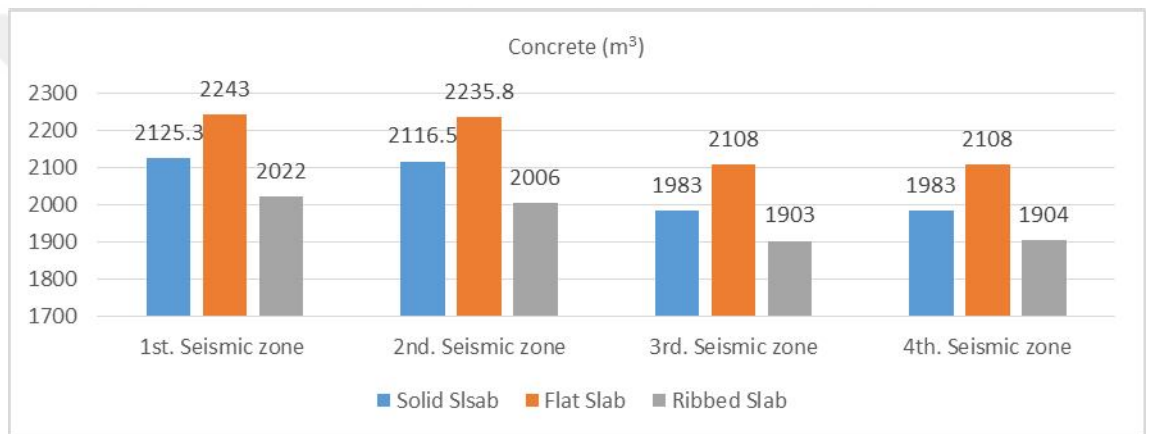


Figure 4.53. Quantities of concrete in 32 classroom's school for the second type of soil (Z2)

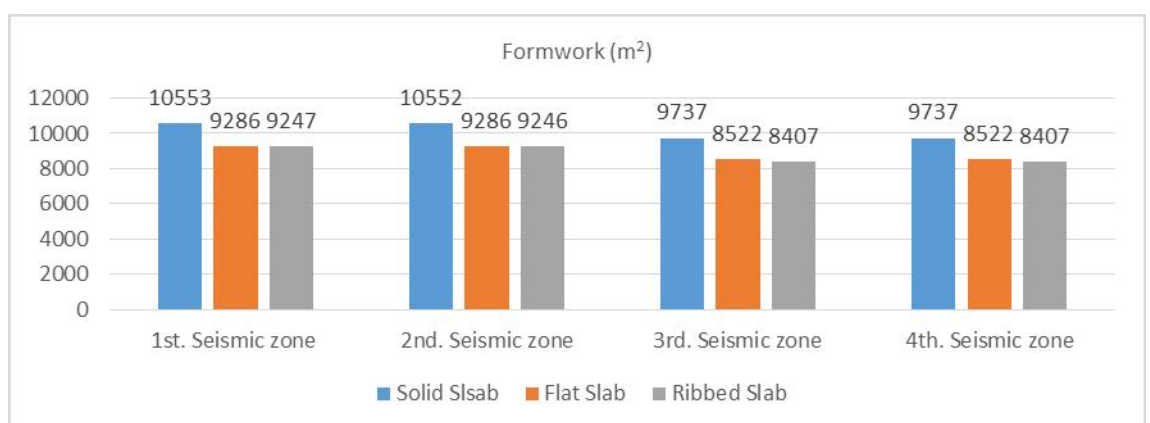


Figure 4.54. Quantities of formwork in 32 classroom's school for the second type of soil (Z2)

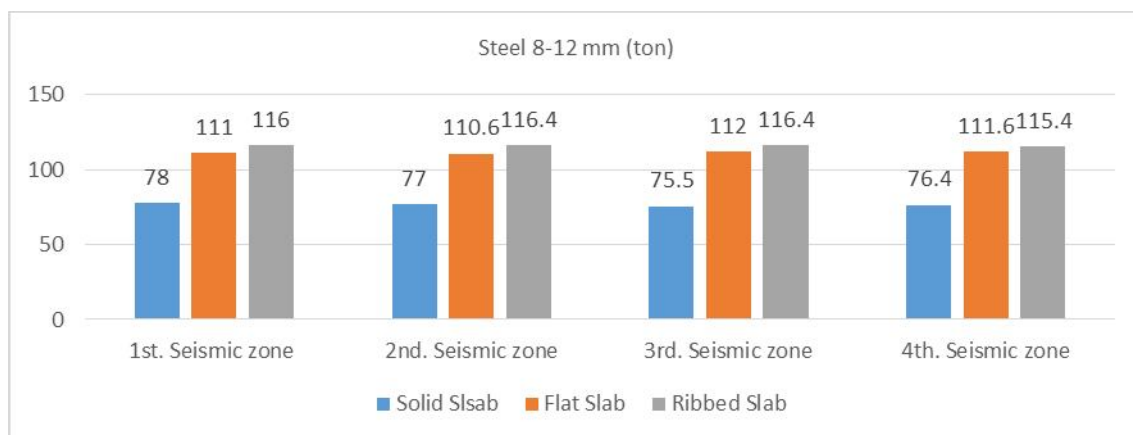


Figure 4.55. Quantities of steel (8-12 mm) in 32 classroom's school for the second type of soil (Z2)

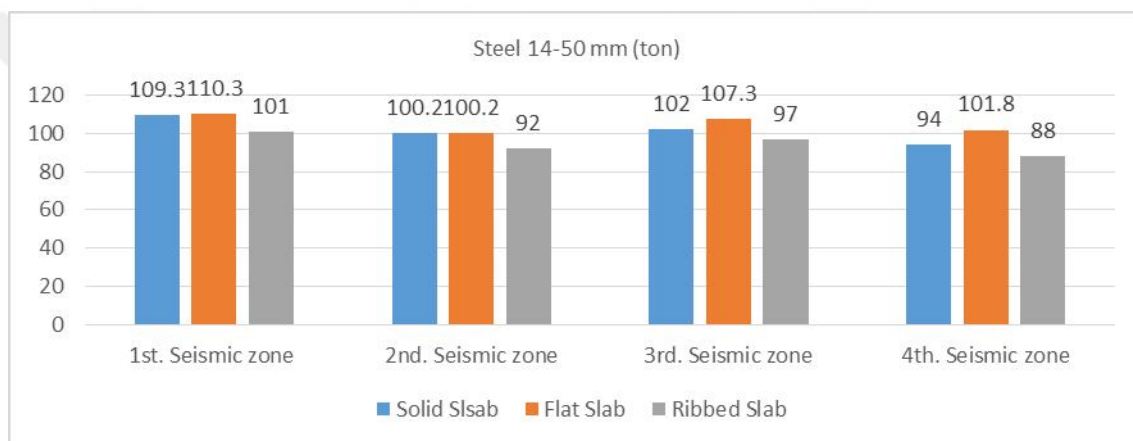


Figure 4.56. Quantities of steel (14-50 mm) in 32 classroom's school for the second type of soil (Z2)



Figure 4.57. Quantities of concrete in 32 classroom's school for the third type of soil (Z3)

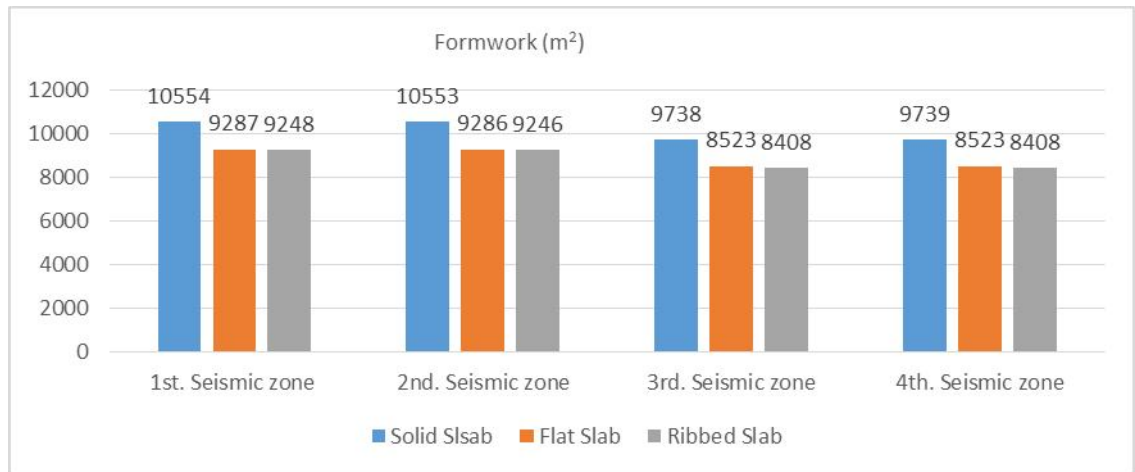


Figure 4.58. Quantities of formwork in 32 classroom's school for the third type of soil (Z3)



Figure 4.59. Quantities of steel (8-12 mm) in 32 classroom's school for the third type of soil (Z3)

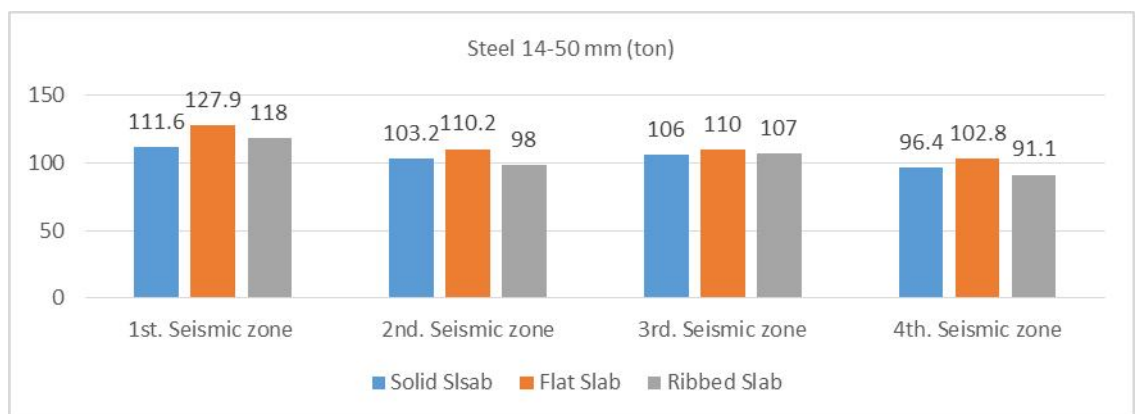


Figure 4.60. Quantities of steel (14-50 mm) in 32 classroom's school for the third type of soil (Z3)

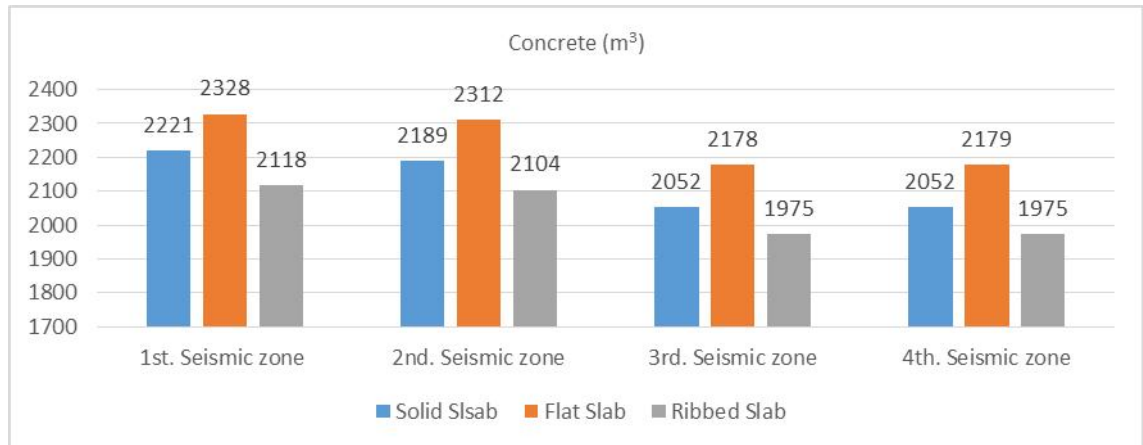


Figure 4.61. Quantities of concrete in 32 classroom's school for the fourth type of soil (Z4)



Figure 3.62. Quantities of formwork in 32 classroom's school for the fourth type of soil (Z4)



Figure 3.63. Quantities of steel (8-12 mm) in 32 classroom's school for the fourth type of soil (Z4)

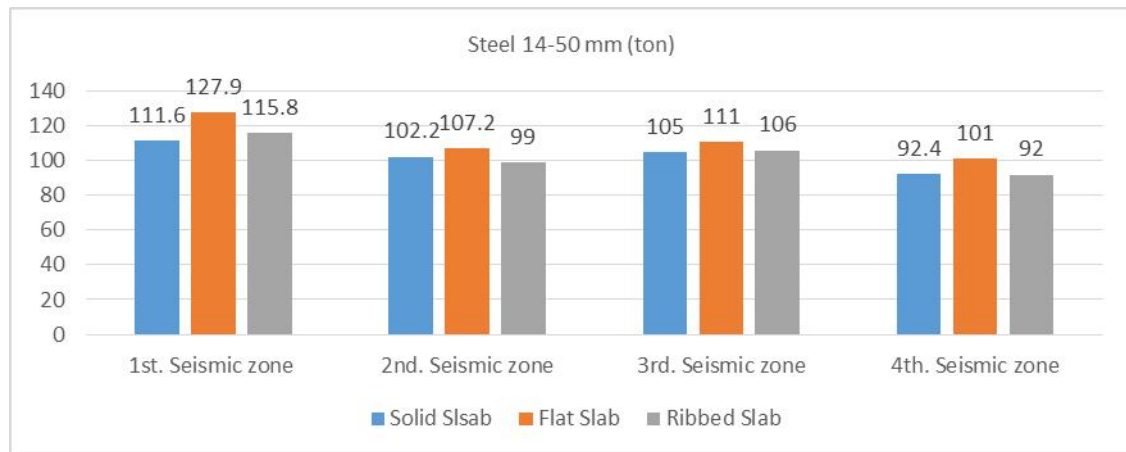


Figure 4.64. Quantities of steel (14-50 mm) in 32 classroom's school for the fourth type of soil (Z4)

4.2. Discussion

According to the charts and tables above, the differences in the quantities of materials (concrete, formwork, and steel) between the school's models can be noticed. In addition, the differences in structural behaviors like weight, seismic forces, and other behaviors between models can be noticed. These differences between models are due to differences in flooring systems, seismic zones, and soil types that are used in this study. The differences can be classified into structural behaviors and quantities of structural materials. These differences will be classified into two types:

- Differences in quantities of structural materials

Structural materials are classified into three main materials, formwork, concrete, and steel. Due to concrete, the quantities of concrete are different in models due to the flooring systems, the four seismic zones, and to the four soil types that are used in this study. From the charts, the ribbed structural system requires the least amount of concrete in all school models, in all seismic zones and above all soil types can be seen, because the empty regions between ribs are filled up by hollow blocks. While the flat flooring system requires the most quantities of concrete in all models because the slab thickness should be high to solve the punching shear problems and this leads to increase the self-weight of the slab, sections of columns or shear wall, and this leads to increase the concrete quantities.

According to formwork, the quantities of formwork are different in models due to the flooring systems, the four seismic zones, and the four soil types that used in this study. According to the charts, the solid flooring system requires the most formwork in all school models, in all seismic zones and above all soil types. While the flat flooring system and ribbed flooring system have a similar quantity of formwork, or there are slight differences in the amount of formwork between them.

According to steel, the quantities of steel are different between models due to the flooring systems, seismic zones, and the soil types that used. In this study steel was classified into two groups according to steel diameter as the following:

- Steel diameter between 8-12 mm: When we look at the charts, in 8 classroom school and 32 classroom school, the ribbed structural system requires the most quantities of steel diameter 8-12 mm, in all seismic zones and above all soil types. While the solid flooring system requires the least quantities of steel diameter 8-12 mm that used in this study.

In 16 classroom school, the ribbed flooring system requires the most quantities of steel diameter 8-12 mm, in all seismic zones and above all soil types. While the flat flooring system requires the least quantities of these diameter of steel.

In 24 classroom schools, the flat flooring system requires the most quantities of steel diameter 8-12 mm, in all seismic zones and above all soil types. While the solid flooring system is the least structural system that required these diameter of steel.

- Steel diameter between 14-50 mm: When we look at the charts, in 8 classroom school and 16 classroom school, the ribbed structural system requires the most quantities of steel diameter 14-50 mm, in all seismic zones and above all soil types. While the solid flooring system is the least structural system that uses these diameter of steel .

In 24 classroom school and 32 classroom school, the flat flooring system requires the most quantities of steel diameter 14-50 mm, in all seismic zones and above all soil types. While the ribbed

flooring system requires the least amount of these diameter of steel

In general, in the 8 classroom's school models and 16 classroom's schools models, the ribbed flooring systems require steel more than other types of flooring systems to resist the high moment and shear and tension that generated on the slab, while solid flooring systems require the least amount of steel because the regular distribution of loads is from slab to beams then to columns and foundations. In 24 classroom's school's models and 32 classroom's school's models, the flat flooring systems require the most quantities of steel because the spans between columns are not as large as the 8 or 16 classroom's school's models. For this reason, the slab thickness in solid flooring system is not thick, but in flat flooring system should be very thick to resist the punching shear that occurs in connections area between slab and columns. This increasing in slab thickness lead to increase the amount of steel.

- Differences in structural behaviors

The results of analysis are very complicated, for this reason it cannot discuss all behaviors. Only some important points of structural behaviors will be showed. According to building natural vibration period (T), in all structural models, the structures that have ribbed flooring systems, have a natural vibration period more than other types of structures. While this period in structures that have solid flooring systems is less than the other structures.

According to the weight of buildings, in all structural models, the structures that have flat flooring systems, have a weight more than other types of structures. While the structures that have a solid flooring system are lighter than the other structures. In some seismic zones, the weight of structures that have ribbed flooring systems is very near to the weight of structures that have flat flooring systems. The reason behind the flat flooring systems are heavier than other flooring types is that the spans

between supports are not large in all models, the spans are between 4 to 6 m. for this reason, the thickness of slabs in solid flooring systems is not large. While the thickness of slabs in flat flooring systems is very large because of the punching shear that occurs in the connection area between columns and slabs. This increasing of self-weight of the slab lead to increase the dimensions of columns. Consequently, the structure will be very heavy.



5. CONCLUSION

This study is made to compare the economic cost between three types of flooring systems. These type of flooring systems are solid flooring system, flat flooring system, and ribbed flooring system. The analysis and structural calculations are made for four schools that are different in size and architecture plans (8, 16, 24, and 32 classroom's schools). The analysis and structural calculations are made according to the four seismic zones (1st, 2nd, 3rd, and 4th seismic zones) and according to the four types of soil (Z1, Z2, Z3, and Z4) that are mentioned in Turkish Earthquake Code 2007. The codes that are used in this study are TS 500 and Turkish Earthquake Code 2007. All calculations and analysis of all models in this study are made by using STA4CAD software program. The quantities of formwork, concrete, and steel for all models are calculated in this study by using this program.

The results of this study show that quantities of structural materials are different between models in all seismic zones and soil types. In general, the tables and charts in chapter 4 show that the ribbed flooring structures require the least amount of formwork while the solid flooring structures require the most amount of formwork because of having beams. According to concrete quantities, ribbed flooring system require the least amount of concrete because the gaps or voids between ribs are filled up by hollow blocks. While the flat flooring systems require the most quantities of concrete. According to steel quantities, tables and charts show in 8 classroom's school models and 16 classroom's schools models, the ribbed flooring systems require steel more than other types of flooring systems to resist the high moment and shear and tension that are generated on the slab, while solid flooring systems require the least amount of steel because of the regular distribution of loads from slab to beams then to columns and foundations. In 24 classroom's school's models and 32 classroom's school's models, the flat flooring systems require the most quantities of steel because the spans between columns are not large like 8 or 16 classroom's school's models.

At the end of this study, the economic and cost factors remains the most important factors in determining the appropriate flooring system for any structure. Selecting the most economical flooring system depends on the price of materials. Today, especially in Turkey, the price of steel is very expensive, so it can be recommended to use the flooring system that requires the least amount of steel.

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CURRICULUM VITAE (C.V)

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EĞİTİM

Derece	Adı, İlçe, İl	Bitirme Yılı
Lise	: Iraq, Erbil	2014
Üniversite	: Erbil University	2018
Yüksek Lisans	: Turkey, Konya, Selcuk university	
Doktora	:	

İŞ DENEYİMLER

Yıl	Kurum	Görevi
2013	KAR Group	Excavation works
2014	Sipan Company	Management works and supervision of concrete casting

YABANCI DİLLER

Engilish (good)
 Turkish (good)
 Kurdish (little)

BELİRTMEK İSTEĞİNİZ DİĞER ÖZELLİKLER

Auto CAD (For drawing any plane)
 ETABS (For analysis and design columns and beam for any structure)
 SAFE (For analysis and design slab or foundation for any structure)
 PROKON
 PRIMOVERA 6 (deal with management and follow the work in the site)

YAYINLAR

HABASH, Z.Z.I., ÖZTÜRK, M., ERKAN, İ.H (2018). The effect of floor systems on the cost of educational buildings, 14th International Conference on Natural and Engineering Science, Bodrum, Turkey.