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Investigation of the effects on earthquake behavior and rough construction costs of the slab type in reinforced concrete buildings

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Abstract. In the architectural design process, the selection and configuration of the structural system significantly affect the earthquake behaviours of the reinforced concrete buildings. The main purpose of this study, the effects on the earthquake performances and the rough construction cost of the buildings of the slab type in reinforced concrete buildings are to examine comparatively for different local soil classes. The results obtained from this study have been determined that the building model having slabs with beams is safer compared to other types of slabs, especially when considering the vertical bearing structural elements (columns). It also shows that other types of slab, except for slab with beams, reduce the earthquake performances of reinforced concrete buildings, increase the displacement values, 1st natural vibration period values and the cost of rough construction. This matter reveals that slab type is quite important and the preference of beamed slabs in reinforced concrete buildings to be constructed in earthquake zones would be more appropriate in terms of safety and cost.

Keywords: slab type; earthquake performance; rough construction cost; Sta4-Cad

1. Introduction

In Turkey where located on one of the world's active earthquake belts have occurred frequently devastating earthquakes (Scawthorn and Johnson 2000, Adalier and Aydingun 2001, Sezen *et al*. 2003, Spence *et al*. 2003, Doğangün 2004, Kaplan *et al*. 2004, Arslan and Korkmaz 2007, Celep *et al*. 2011, Ural 2013, Di Sarno *et al*. 2013). It is aimed that the reinforced concrete buildings will not collapse in the face of these earthquakes and / or overcome the earthquake with damages that do not result in loss of life due to their ductility properties. The design phase, especially during earthquakes, it is necessary to correctly determine the loads that will come to the structural elements and designs must be made in accordance with these loads. However, another feature expected from reinforced concrete buildings is that they are designed economically.

When designing reinforced concrete buildings, different slab types are selected in accordance with the intended use and it is clear that this will affect the earthquake behavior and cost of the building. However, change of slab types can generate differences in the transport safely of both vertical and horizontal loads in the structural system (Öztürk 2013, Uludağ 2019, Gürsoy and Doğan 2020). Therefore, it is quite important in terms of design to know the working principles, support conditions and economic spans of reinforced concrete slab types. On the other hand, slab types affect the rigidity and ductility of the building. However, due to the aesthetic concerns, especially with the influence of architects, slab type without beams is chosen. This matter requires increasing in the slab thickness to ensure adequate safety against stapling effects. Therefore, when choosing the slab type, the slab thickness should be optimized by considering enough safety, cost and aesthetic concerns together. Thus, it is possible to realize a safe design against earthquakes thanks to its strength, stiffness and ductility properties. Also, well-arranged architectural designs are necessary certainly for withstanding destructive earthquake loads (Inan *et al*. 2012, Inan *et al*. 2014). On the other hand, it is necessary for earthquake resistant buildings design that different engineering and architectural disciplines should be in cooperation (Gürsoy *et al*. 2015). Because it is seen that the structural irregularities in the architectural design are directly or indirectly related to when the reasons collapsed or damaged of the reinforced concrete buildings are examined (Gürsoy 2014).

Some studies have been carried out to determine the earthquake behaviors of different slab types, slab opening, and structural irregularities used in reinforced concrete buildings (Terzi and Elçi 2006, Ulucan ve Yön 2008, Terzi and Elçi 2009, Yön *et al*. 2010, Sağlıyan and Yön 2014). In this study, effects on building earthquake behavior and the rough construction costs (steel and concrete) of the types of slab used in reinforced concrete buildings is examined comparatively with the help of Sta4-Cad (Sta4-Cad 2014) program taking into account local soil classes given the Turkey Earthquake Code (TEC 2007). In the reinforced concrete building models having different slab type are investigated effects on earthquake behavior and rough construction cost of different span distance. For this purpose, the structural analyses of reinforced concrete building models consisting 5 main and 13 sub-models performed with Sta4-CAD structural analysis program. Here, it would be appropriate to state that the STA4-Cad

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program uses the matrix displacement method.

2. Slab systems used in reinforced concrete buildings

Structural elements carrying load in the direction perpendicular to their planes and whose one dimension (thickness) is very small compared to the other two dimensions are called slabs. Slabs are generally seated to beams, reinforced concrete walls, carrier masonry walls, bond beam and columns. In addition, reinforced concrete slabs constructed in accordance with the technique contribute to the increase of the horizontal stiffness of the structure, too. Slabs used in reinforced concrete buildings are classified according to different criteria. The concrete slabs considered in this study are classified under three main headings. These,

1) Beamed slabs
   a) Beam slabs (one-way slabs) working in one (single) direction,
   b) Beam slabs working in two (double) directions,
2) Beamless slabs
   a) Beamless slabs without drop panels and column head,
   b) Beamless slabs with drop panels without column head,
   c) Beamless slabs with column head without drop panels,
   d) Beamless slabs with column head and drop panels,
3) Ribbed slab
   a) Ribbed slabs working in one direction,
      √ Unfilled ribbed slabs,
      √Filled ribbed slabs (hollow-tile floor slab),
   b) Ribbed slabs working in two directions (waffle slab),

2.1 Beamed slabs

They are the most preferred slabs systems in the construction of reinforced concrete buildings. The supports of these slab systems consist of beams and / or shear walls (reinforced concrete walls). These slab systems are generally supported on beams at all four sides but are present where they are supported on one or several beams (three, two and one edge). These slab systems with their high rigid diaphragm properties can provide enough resistance against lateral displacements compared to other slab types. In addition, due to its high rigid diaphragm properties, these slab systems are preferred in the design of buildings in regions with high earthquake hazard.

2.2 Beamless slabs

Beamless slabs are slab systems where are located only the slabs in the horizontal plane of the buildings and they are settle directly on the vertical carrying elements (columns and / or shear walls). Beamless slabs are preferred that in buildings where the story height is desired to be kept low, in buildings where a flat ceiling is required, in buildings with partition walls that can be moved when necessary (such as offices etc.), in passing the installations without decreasing the story height, in the basement ceilings without increase the foundation depth and in buildings used for purposes such as storage. In addition, formwork, reinforcement and concrete workmanship is easier than other types of slab are another reason for preference. However, it requires more slab thickness and reinforcement compared to beamed slab. On the other hand, they are advantageous in terms of thermal and sound insulation due to the high slab thickness. Despite that it is possible to summarize the weak sides of the beamless slabs as follows.

√ Earthquake performances is poor compared to other slab systems,
√ High probability of stapling,
√ Requires more reinforcement and concrete (slab) thickness,
√ Vertical bearing elements such as reinforced concrete walls are needed more.

In terms of stapling safety of beamless slab systems, it would be beneficial to support the outer edge supports with beams as much as possible. On the other hand, sit on columns on the axles perpendicular to each other of beamless slab systems provides calculation and construction ease.

According to TEC, if the reinforced concrete walls in buildings with normal ductility level of beamless slabs are not used, only the third- and fourth-degree earthquake zones where the total building height is less than 13 m are permitted. It is mandatory to use reinforced concrete walls in order to limit the damages that may occur in beamless slab systems with normal ductility level to be constructed in the first- and second-degree earthquake zones (TEC 2007).

2.3 Ribbed slabs

The slabs consisting of a thin plate, whose free spans between ribbed are arranged not to exceed 700 mm, are called ribbed slabs. In TS500, if there are strip loads (partition walls, etc.) in the direction perpendicular to the ribbed in these slab systems, it is recommended to consider these as single loads on each ribbed in the calculations. It is also recommended to make a transverse ribbed if these loads are large (TS500 2000). The most important weaknesses of ribbed slabs compared to beam slabs are the worse to earthquake performances.

According to TEC, if any of the conditions given for the ductility levels of high columns, beams and beam-column joints not providing, the filled or unfilled ribbed (ribbed slabs working in one direction) and cassette (ribbed slabs working in two directions) is recommended as normal systems to ductility level. In addition, it is stated that if the shear walls in the building of normal ductility level systems are not used, it can be made only in the third- and fourth-degree earthquake zones and if the total height of the building is less than 13 m. The use of shear walls to limit the damages that may occur in the ribbed slabs with normal ductility level to be constructed in the first and second earthquake zones is obligatory. In these slab systems, they are divided into two classes as ribbed slabs working in one and two directions like beamed slabs.

Detailed information relating to the design conditions of the slab systems used in reinforced concrete buildings can be found from the several references (TS500 2000, TEC 2007, Celep and Kumbasar 2018, Doğangün 2018).

3. Matters to be considered for design according to earthquake of reinforced concrete slabs

In the reinforced concrete buildings in Turkey is seen that resulting from earthquakes occurring most of the slab damages. When this is the case, these structural elements should be designed to withstand earthquakes.

3.1 Gaps in slabs

There may be slab gaps in different shapes and sizes in buildings due to various reasons (light, stairs, elevator and mechanical etc.). In buildings with slab gap, the ratio of the gap to the floor plan and its place in the floor plan is very important. Because the load transfer from the slab is of a small length, if the slab gaps are close to especially the shear wall edges. Therefore, the continuation of the beams along the slab gaps is very important in terms of the behavior of the building.

3.2 Slab discontinuities (A2)

In TEC, A2–slab discontinuity in the slab in any floor,

√ Including stairs and elevator gaps, the total slab gaps be more than 1/3 of the gross floor area,

√ Local floor gaps, which make it difficult to transfer safely to vertical structural elements of earthquake loads,

√ Being sudden reductions in the rigidity and strength in-plane of the slab,

the conditions are defined as (TEC 2007).

3.2.1 Buildings that slabs work as rigid diaphragms

Storey slabs that earthquake loads take parallel to their planes, be transferred these loads to vertical structural elements and cause the shear forces to occur in these elements. In other words, shear forces and moment effects have occurred on the slabs due to the earthquake loads. Condition to provide the storey slabs drift together due to earthquake loads can be called as the rigid diaphragm. In order to achieve this matter, the in-plane bending stiffness of said storey slab must be large. It is obvious that with various reasons reduce this rigidity of the gaps in the storey slabs.

3.2.2 Buildings whose slabs do not work as rigid diaphragms

The earthquake loads acting in their planes of the storey slabs do not transferred safely the vertical structural elements, hence it is status that the drift of each frame is different. As a result of this different drift, different shear forces are formed in the structural elements. In the static calculation of the slabs that do not work as rigid diaphragms, the finite element model which is formed by dividing the slab into an enough three-dimensional shell elements are used (TEC 2007). In this case, to consider, the additional eccentricity effect, each of the point masses distributed at various points on each floor is shifted by ± 5% of the storey size in the direction perpendicular to the earthquake direction.

Table 1 Design parameters of the building models considered

Earthquake zone		1
Effective ground acceleration coefficient (A_0)		0,4
Building importance factor (I)		1
The structural behavior factor (R)		4
Live load factor		0,3
Design Spectrum characteristic periods (s)	for Z1 soil class	T_A=0,10 / T_B=0,30
	for Z2 soil class	T_A=0,15 / T_B=0,40
	for Z3 soil class	T_A=0,15 / T_B=0,60
Allowable bearing values of the foundation soils (kN/m^2)	for Z1 soil class	1500
	for Z2 soil class	500
	for Z3 soil class	200
Bedding values of the foundation soils (kN/m^3)	for Z1 soil class	300000
	for Z2 soil class	100000
	for Z3 soil class	30000
Live load (kN/m^2)		2
Concrete young's modulus (MPa)		30000
Steel young's modulus (MPa)		200000

4. Reinforced concrete building models and numerical applications

In this study, for the numerical applications, symmetrical in plan and reinforced concrete building models consisting 5 main and 13 sub-models were selected as 5 storey with four spans in both directions. In addition, to avoid additional internal forces due to structural torsion, the stiffness distribution in both directions in the plan of the selected building models is taken symmetrically and the stiffness center and center of mass are overlapped. On the other hand, it is assumed that cross-sectional dimensions of all columns are 50 x 50cm and the storey heights are 3 m in all building models considered in numerical applications. Also, in all models are designed to have same story gross area and beams and columns have same sectional dimensions. According to Turkey building code requirements for reinforced concrete (TS500 2000), are developed by considering 25 MPa concrete strength and 420 MPa yield strength of reinforcement steel bars (Uludağ 2019). Other structural features and design parameters related to selected reinforced concrete building models are given below,

√ In Model 1, beamed slab is selected, cross-sectional dimensions of all beams are assumed to be 30 x 60cm and slab thickness is 12 cm.

√ In Model 2, ribbed slabs working in one (single) direction is selected as the slab type, cross-sectional dimensions of all main beams are assumed to be 30×60 cm, width of the ribbed is 10cm, height of the ribbed is 30 cm, distance between the ribbed is 50 cm and thickness of the slab is 7 cm.

√ In Model 3, ribbed slabs working in two directions

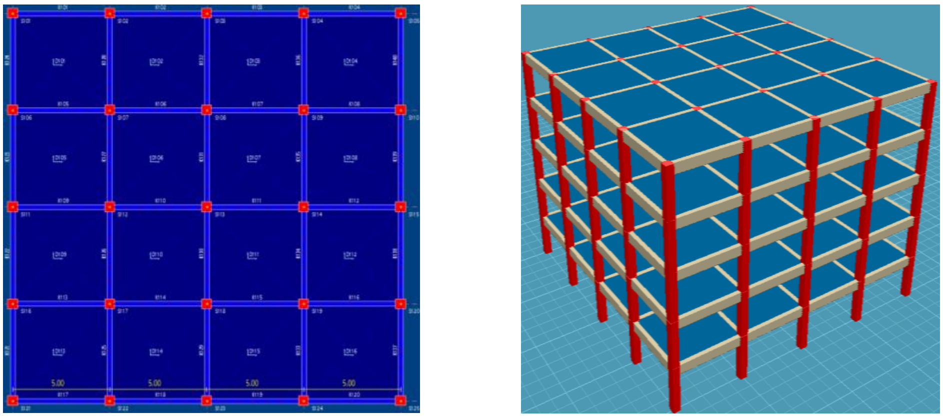


Fig. 1 Views from the 5-storey and floor plan of model 1

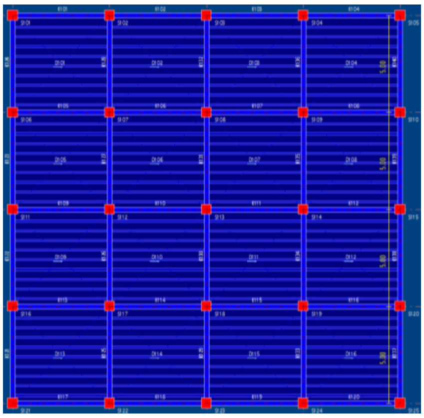


Fig. 2 View from the storey plans of model 2

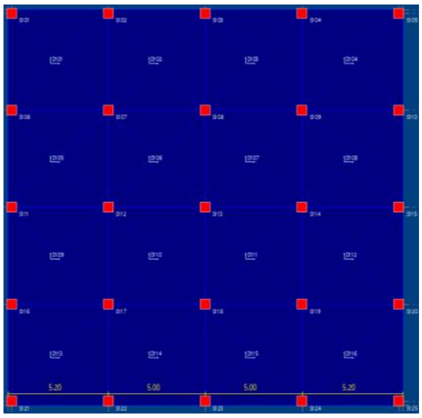


Fig. 4 View from the storey plans of model 4

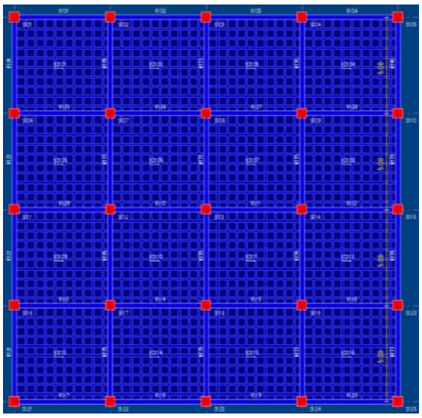


Fig. 3 View from the storey plans of model 3

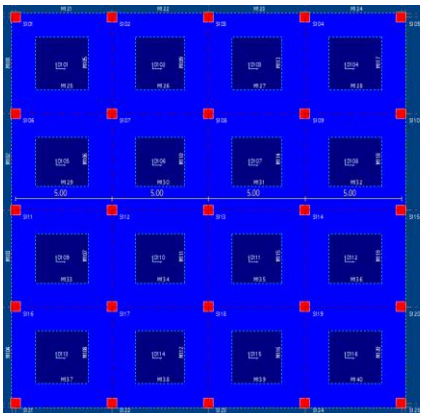


Fig. 5 View from the storey plans of model 5

(waffle slab) is selected as the slab type, cross-sectional dimensions of all main beams are assumed to be 30×60 cm, the width of the ribbed in both directions is 10 cm, height of the ribbed is 30 cm, distance between the ribbed is 50 cm and thickness of the slab is 7 cm.

√ In Model 4, the beamless slab is selected, and the slab thickness is assumed to be 25 cm.

√ In Model 5, slab having plane beams chosen as the slab type. It is accepted that the cross-sectional dimensions of all plane beams in the interior are 250×30 cm, the cross-sectional dimensions of all pillow beams in the outside are 125×30 cm and the slab thickness is 25 cm.

Floor plans and views of reinforced concrete building models taken into consideration in numerical applications are given in Figs. 1-5, respectively. In all building models seen in these figures, storey areas are selected equally. In addition, other the design parameters used in the structural analyses are given in Table 1.

5. Findings and evaluations

If the distances between the axes in the x and y directions of the reinforced concrete building models considered in this study are 5×5 m, 6×6 m and 7×7 m

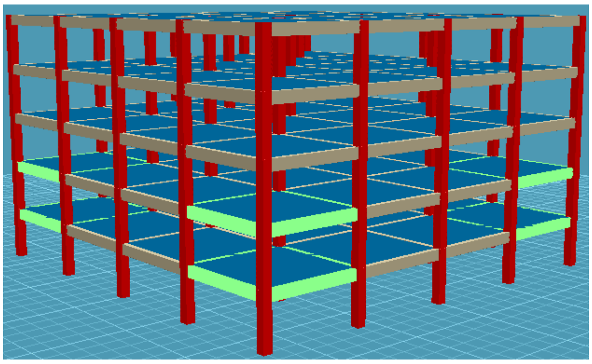


Fig. 6 A view of inadequate structural elements of model 1 for the Z3 soil class if the axle distances are 6×6 m

respectively, the views of the insufficient structural elements as a result of the structural analyses performed by Sta4-CAD structural analysis program for the three different (Z1, Z2 and Z3) soil groups proposed in the TEC are given in Figs. 6-14, respectively. From these figures,

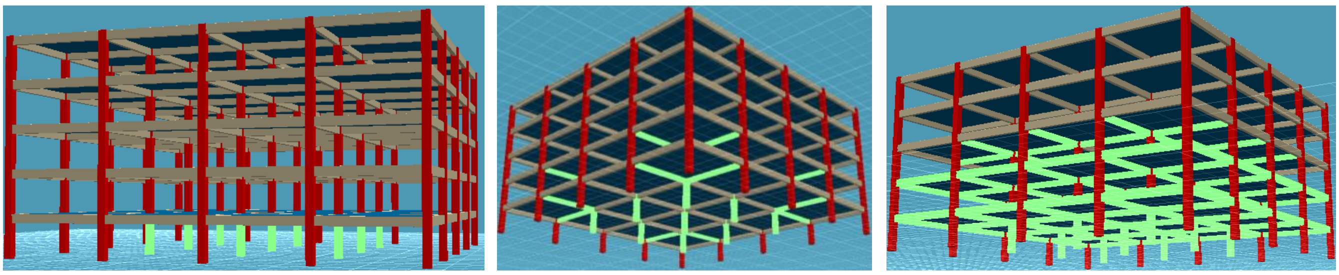
√ In model 1; it is seen that if the axle spans are 6×6 m, some beam dimensions of the ground story and 1st storey are insufficient for the Z3 soil class. Also, it is seen that if the axes spans are 7×7 m, the some column dimensions of ground story for Z1 soil class are insufficient, some column-beam dimensions of the ground story and the some beam dimensions of 1st storey for Z2 soil class are insufficient and the some column dimensions of ground storey and all beams dimensions of ground storey and 1st storey and some beam dimensions of 2nd storey for Z3 soil class are insufficient (see Fig. 6 and Fig. 7).

√ In model 2; it is seen that if the axle spans are 6×6 m, some beam dimensions of the ground story and 1st storey are insufficient for the Z2 soil class and some beam dimensions of the ground-1st-2nd storey are insufficient for the Z3 soil class. Also, it is seen that if the axes spans are 7×7 m, the some column-beam dimensions of ground story for Z1 soil class are insufficient, some column-beam dimensions of the ground story and the some beam dimensions of 1st and 2nd storey for Z2 soil class are insufficient and the some column-beam dimensions of ground storey and some beam dimensions of 1st-2 nd-3rd stories for Z3 soil class are insufficient (see Fig. 8 and Fig. 9).

√ In model 3; it is seen that if the axle spans are 6x6 m, some beam dimensions of the ground-1st-2nd stories are insufficient for the Z3 soil class. Also, it is seen that if the axes spans are 7×7 m, the some column dimensions of ground story for Z1 soil class are insufficient, some column-beam dimensions of the ground story and the some beam dimensions of 1st storey for Z2 soil class are insufficient and the some column dimensions of ground storey, all beam dimensions of ground-1st stories and some beam dimensions of 2nd storey for Z3 soil class are insufficient (see Fig. 10 and Fig. 11).

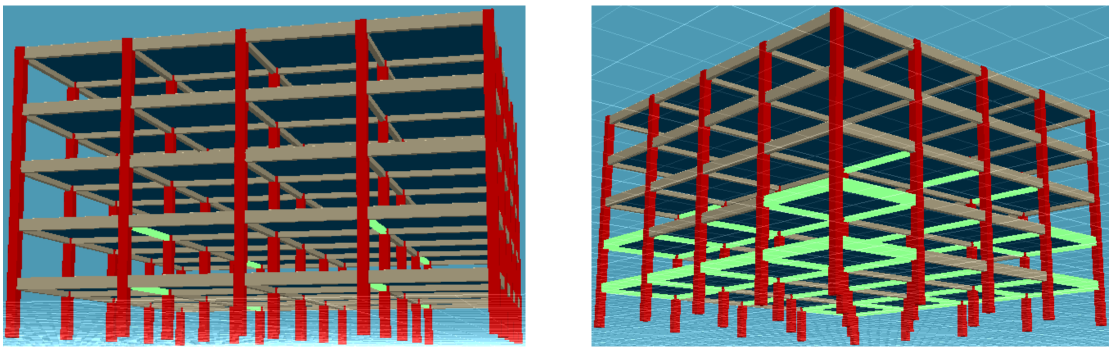
√ In model 4; it is seen that if the axle spans are 5×5 m, slab dimensions on all stories for the Z1 and Z2 soil classes are insufficient and all column dimensions of ground story and the slab dimensions on all stories for the Z3 soil class are insufficient (see Fig. 12).

√ In model 5; it is seen that if the axle spans are 6×6 m, some column dimensions of the ground and 1st stories are insufficient for the Z3 soil class. Also, it is seen that if the axes spans are 7×7 m, the some column



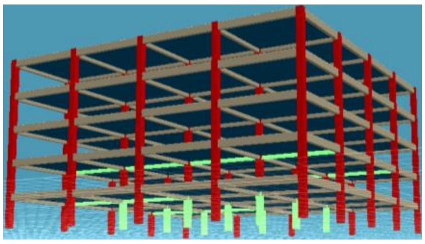
For soil class Z1 For soil class Z2 For soil class Z3

Fig. 7 Views of inadequate structural elements of model 1 for different soil classes if the axle distances are 7×7 m

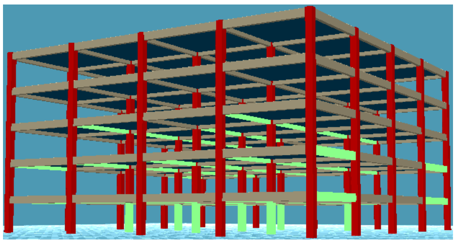


For soil class Z2 For soil class Z3

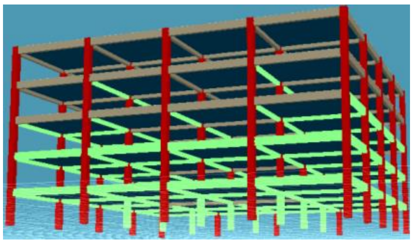
Fig. 8 Views of inadequate structural elements of model 2 for the Z2-Z3 soil classes if the axle distances are 6×6 m



For soil class Z1



For soil class Z2



For soil class Z3

Fig. 9 Views of inadequate structural elements of model 2 for different soil classes if the axle distances are 7×7 m

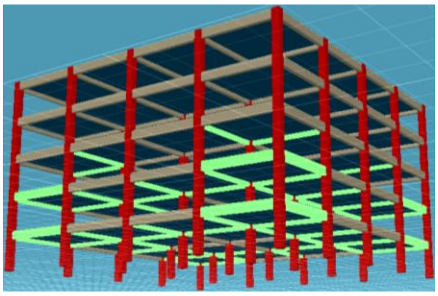
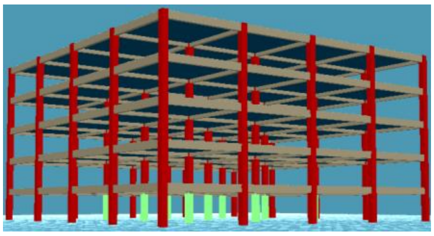
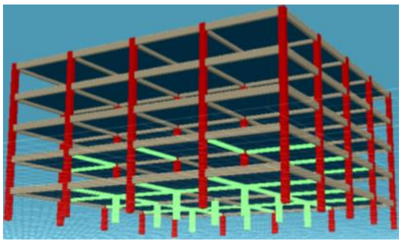


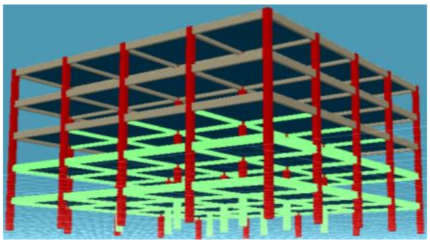
Fig. 10 A view of inadequate structural elements of model 3 for the Z3 soil class if the axle distances are 6×6 m



For soil class Z1



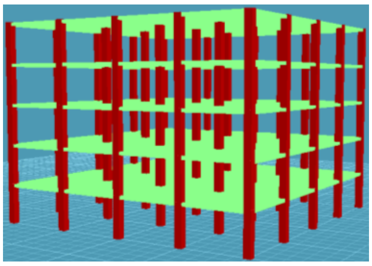
For soil class Z2



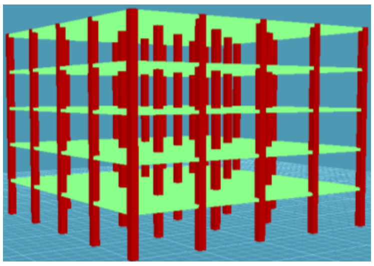
For soil class Z3

Fig. 11 Views of inadequate structural elements of model 3 for different soil classes if the axle distances are 7×7 m

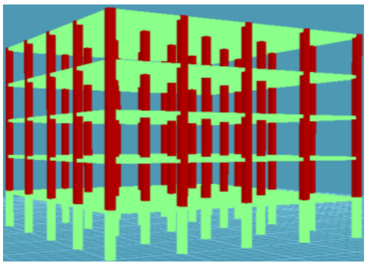
dimensions of ground-1st-3rd stories for Z1 soil class are insufficient, some column dimensions of ground-1st-2nd-3rd stories for Z2 soil class are insufficient and all column dimensions of ground storey and some column dimensions of 1st-2nd-3rd stories for Z3 soil class are insufficient (see Fig. 13 and Fig. 14).



For soil class Z1



For soil class Z2



For soil class Z3

Fig. 12 Views of inadequate structural elements of model 4 for different soil classes if the axle distances are 5×5 m

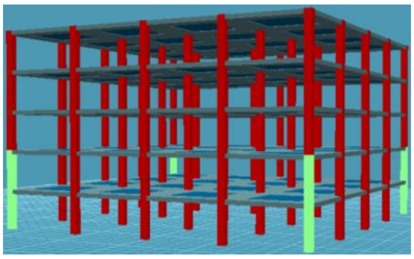
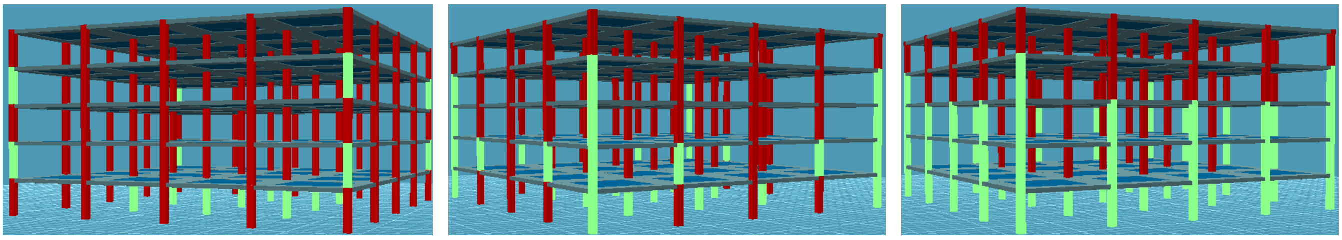


Fig. 13 A view of inadequate structural elements of model 5 for the Z3 soil class if the axle distances are 6x6m

This result reveals that model 1 (building model with beamed slab) is safer than other building models considered in this study when vertical structural elements (columns) are considered.

Here, it would be appropriate to state that if the axle



For soil class Z1 For soil class Z2 For soil class Z3

Fig. 14 Views of inadequate structural elements of model 5 for different soil classes if the axle distances are 7x7m

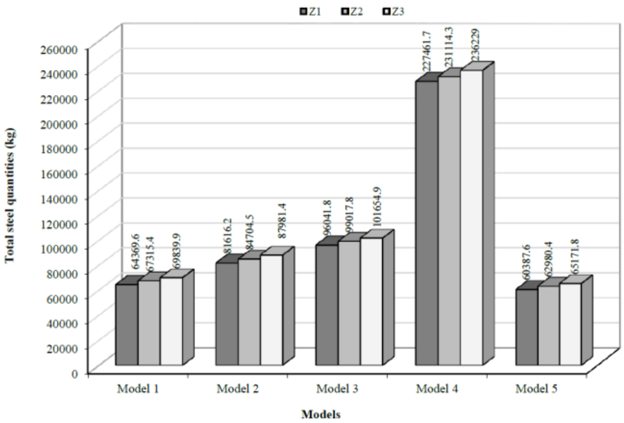


Fig. 15 Distributions of total steel quantities of the building models considered in the case of axle spans of 5x5 m according to the soil classes Z1, Z2 and Z3

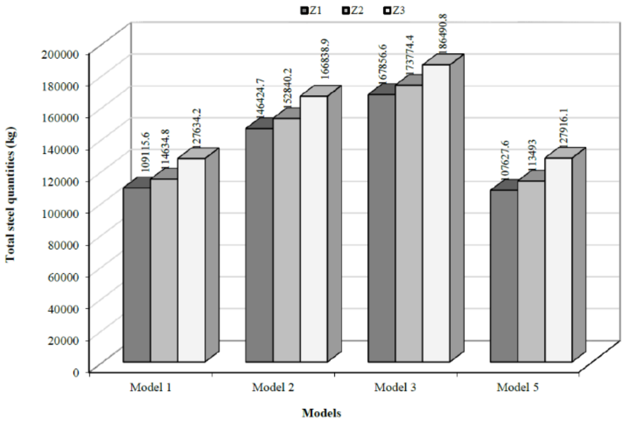


Fig. 17 Distributions of total steel quantities of the building models considered in the case of axle spans of 7x7 m according to the soil classes Z1, Z2 and Z3

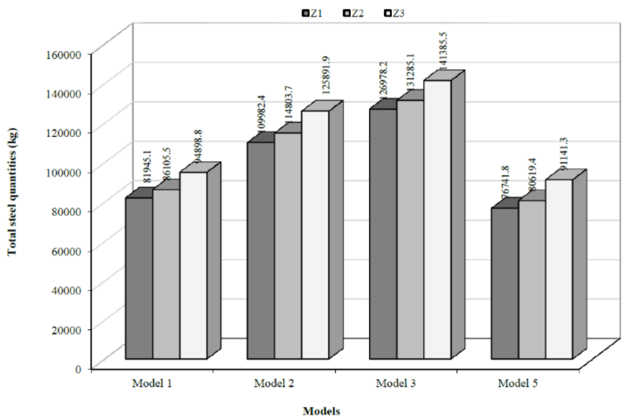


Fig. 16 Distributions of total steel quantities of the building models considered in the case of axle spans of 6x6 m according to the soil classes Z1, Z2 and Z3

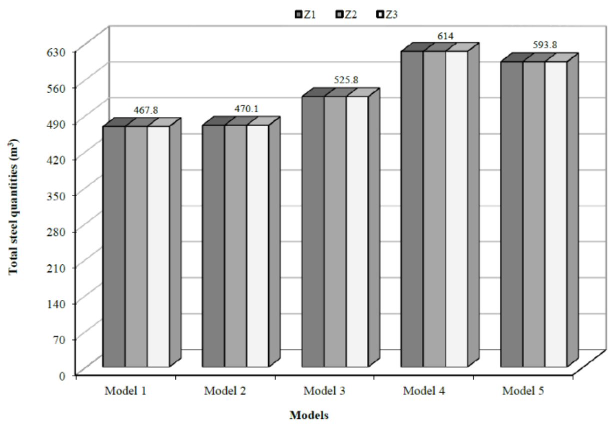


Fig. 18 Distributions of total concrete quantities of the building models considered in the case of axle spans of 5x5 m according to the soil classes Z1, Z2 and Z3

distances are 5×5 m, the slab dimensions of model 4 for three different local soil classes proposed in TDY are insufficient in all floors and other structural elements with increasing axle spans do not provide enough safety. In addition, it should be noted that in case of axle spans of 5×5 m other building models considered in this study are enough all structural elements for soil classes proposed in TDY. For this reason, the model 4, which is not economic and of enough safety, will not be considered in other comparisons (except steel and concrete quantity) in this study.

With the Sta4-CAD structural analysis program of the reinforced concrete building models taken into consideration in this study, in case of the axle spans are 6x6 m and 7×7 m, variations of the total reinforcement (steel) and concrete quantities obtained from the structural analyzes performed for the local soil classes Z1, Z2 and Z3 are given Figs. 15-20, respectively. As seen in Figs.15-20, the smallest total steel quantities obtained from the building models are calculated generally from model 5. However, it is seen that the difference between the amount of steel obtained from model 5 and model 1 decreases with increasing axle spans. In addition, it is seen that in all building models taken into consideration in this study, total steel values obtained increases as local soil class increases from Z1 to Z3. On the other hand, as the axle spans

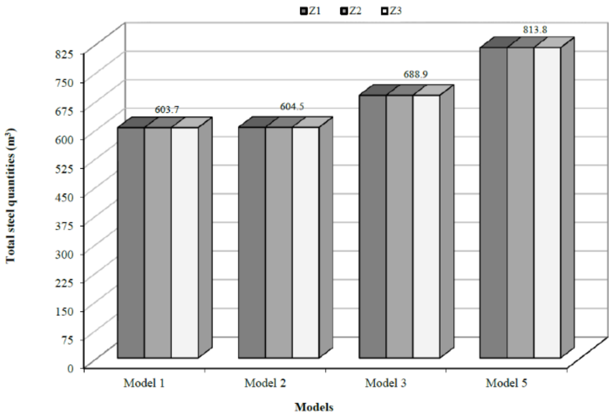


Fig. 19 Distributions of total concrete quantities of the building models considered in the case of axle spans of 6x6 m according to the soil classes Z1, Z2 and Z3

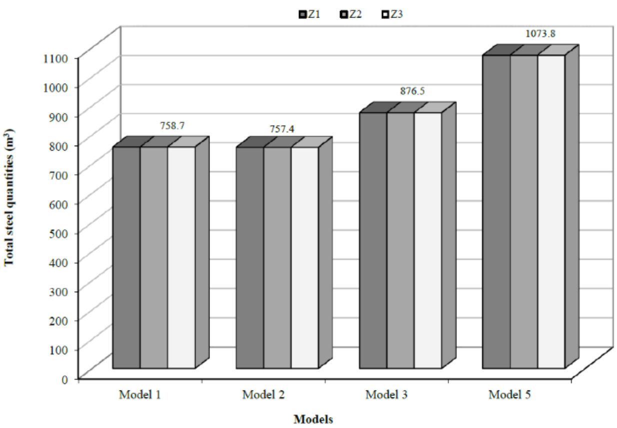


Fig. 20 Distributions of total concrete quantities of the building models considered in the case of axle spans of 7x7 m according to the soil classes Z1, Z2 and Z3

increase, the total steel quantities obtained increase. In Figs. 18-20, it seen that the lowest total concrete quantities values are obtained from model 1 and the total concrete quantities does not change according to local soil classes. In addition, it is seen that the total concrete quantities obtained by increasing the axle spans increases. These findings show that model 1 is more economical than other building models.

Here, it would be appropriate to state that the concrete quantities for the soil classes considered due to the constant size of the structural elements do not change and that the dimensions of these elements will increase in order to provide enough safety in the insufficient structural elements. In addition, it is appropriate to express that the quantities of concrete and steel quantities seen in the figures will be calculated larger due to the increase in cross-sectional dimensions of some structural elements in order to ensure adequate safety in all the building models.

In case of the axle spans are 5×5 m, 6×6 m and 7×7 m, 1st natural vibration periods (T1) and base shear forces obtained from the structural analyses performed with the Sta4-CAD structural analysis program of the building models for the different soil classes (Z1, Z2 and Z3) is given in the Table 2. As can be seen from this table, the

Table 2 Maximum shear forces and 1st natural vibration periods of the building models

Building models	Axle spans (m)	Base shear forces for different soil classes			1st natural vibration periods (T1)
		Z1	Z2	Z3	
model 1	5×5	455,62	573,52	646,84	0,465
	6×6	513,80	646,76	840,18	0,555
	7×7	570,59	718,25	993,46	0,648
model 2	5×5	484,47	609,84	708,28	0,482
	6×6	543,63	684,31	928,84	0,586
	7×7	600,13	755,43	1044,88	0,696
model 3	5×5	473,51	596,05	681,78	0,473
	6×6	530,64	667,96	892,14	0,574
	7×7	585,27	736,73	1019,01	0,682
model 4	5×5	84,66	106,57	147,41	2,843
model 5	5×5	346,32	435,94	516,52	0,495
	6×6	403,05	507,36	701,76	0,616
	7×7	460,14	579,22	801,15	0,745

minimum period value is calculated from model 1. In other words, it is seen that the period values of the other building models taken into consideration increased compared to the model with beamed slab (model 1). On the other hand, as the local ground class increased from Z1 to Z3 and axle spans increased from 5×5 m to 7×7 m, it was observed that the base shear force values increased in all building models. Moreover, it is seen that an increase in the period values obtained by increasing the axle spans from 5×5 m to 7×7 m. This situation shows that, for different reasons, with decreasing the lateral stiffness of the building is subjected to greater shear force values, thereby reducing the performance of buildings. These findings reveal that both soil type and slab type are very important in terms of earthquake safety of reinforced concrete buildings.

In this study, if the axle spans of the building models taken into consideration are 6×6 m and 7×7 m, displacement distributions obtained along building height (at story levels) from the structural analyses performed for different local soil classes by Sta4-CAD program are given in Figs. 21-26, respectively. As can be seen from these figures, the displacement values obtained from model 1 are smaller than the other building models considered in this study. In addition, the displacement values obtained increase as the local soil class becomes more flexible. These findings reveal that model 1 behaves better than other building models considered with this aspect, in other words, performs better.

With the Sta4-CAD structural analysis program of the building models considered, steel amounts obtained from the structural analyses performed for the soil classes Z1, Z2 and Z3 in case the axle clearances are 5×5 m, 6×6 m and 7×7 m are given in Table 3. As can be seen from this table, the amount of steel per square meter obtained from the building models (except for model 5) decreases with increasing axle spans. On the other hand, it is seen that the steel quantity values per 1 m^2 increase with the increase of soil class from Z1 to Z3 in all building models considered. In addition, it is seen that for all soil classes (except for 7×7

Table 3 Reinforcement (steel) quantity values per m^2 according to soil classes and different axle spans of building models

Models	The amount of reinforcement (steel) per m^2 (*kg*)								
	Z1			Z2			Z3		
	5×5m	6×6m	7×7m	5×5m	6×6m	7×7m	5×5m	6×6m	7×7m
model 1	31,24	27,75	27,24	32,67	29,16	28,62	33,89	32,14	31,87
model 2	39,61	37,25	36,56	41,10	38,88	38,16	42,70	42,63	41,66
model 3	46,61	43,00	41,91	48,05	44,46	43,39	49,33	47,88	46,57
model 5	29,30	25,99	26,87	30,56	27,30	28,34	31,62	30,86	31,94

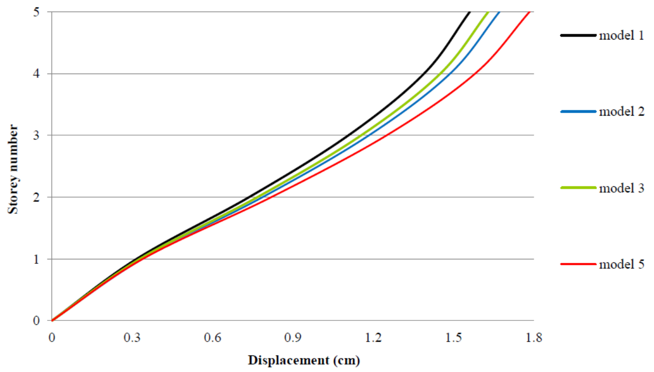


Fig. 21 Maximum displacement values at storey levels of building models for Z1-soil class in the case of the axle spans of 6×6 m

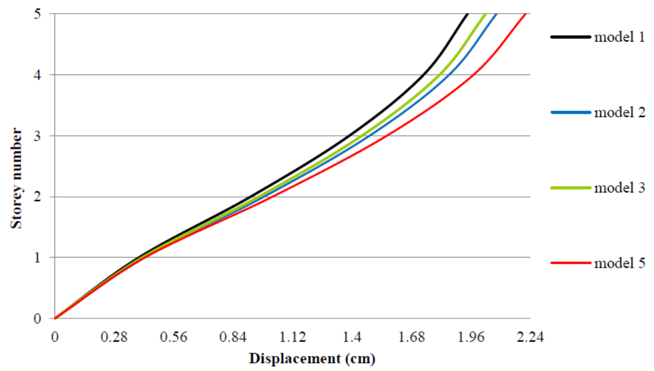


Fig. 22 Maximum displacement values at storey levels of building models for Z2-soil class in the case of the axle spans of 6×6 m

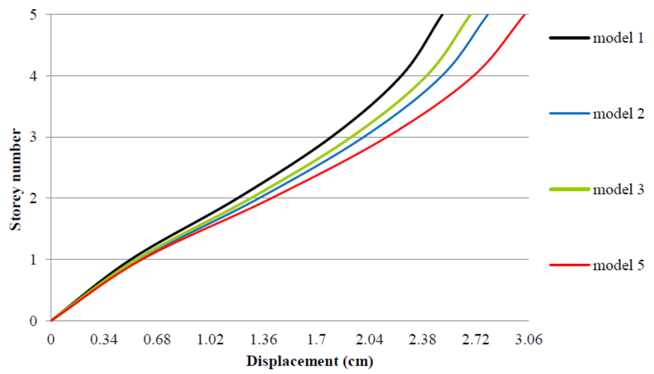


Fig. 23 Maximum displacement values at storey levels of building models for Z3-soil class in the case of the axle spans of 6×6 m

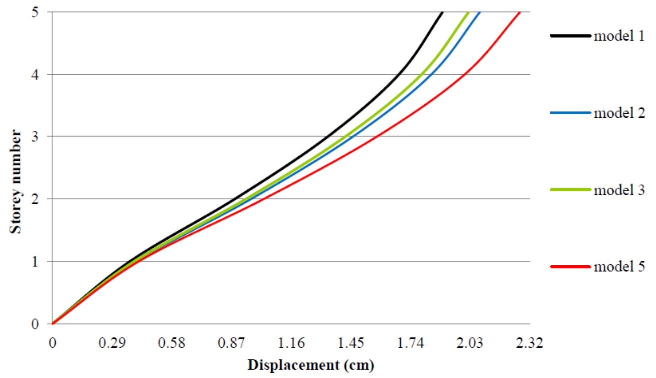


Fig. 24 Maximum displacement values at storey levels of building models for Z1-soil class in the case of the axle spans of 7×7 m

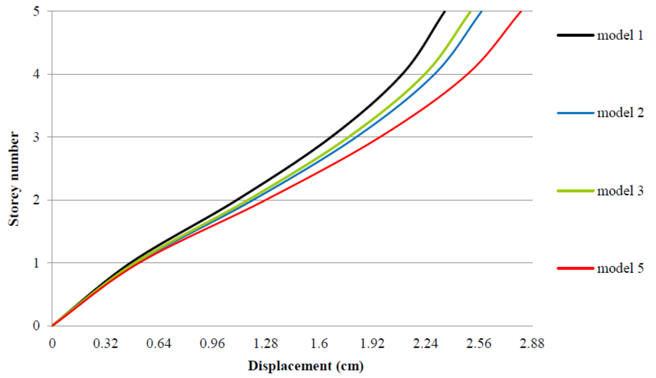


Fig. 25 Maximum displacement values at storey levels of building models for Z2-soil class in the case of the axle spans of 7×7 m

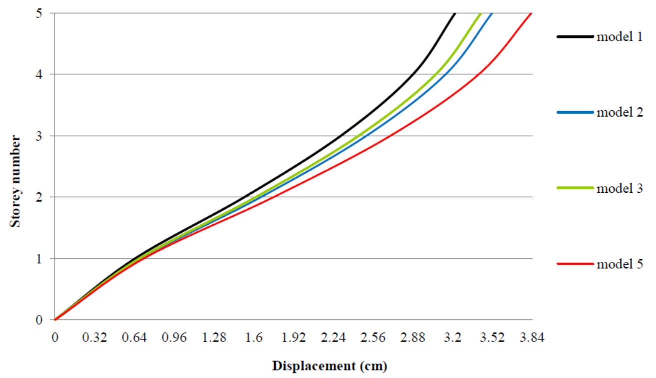


Fig. 26 Maximum displacement values at storey levels of building models for Z3-soil class in the case of the axle spans of 7×7 m

m-Z3 soil class), the lowest steel quantity values to per m^2 are obtained from model 5. However, unlike other building models with the formation of insufficient structural elements when the axle span of the model 5 is 7×7 m, the amount of reinforcement per m^2 increases. Obtained these findings show that model 1 and model 5 are more economical than other building models.

Here, it should be noted that the grayscale seen in the table represents building models with insufficient structural elements.

5. Conclusions

In this study, the effects on building earthquake behaviour and rough construction costs of slab types used in reinforced concrete buildings were investigated comparatively according to three different soil types (Z1, Z2 and Z3) proposed in TDY-2007. The main results and recommendations obtained from the structural analyses performed within the scope of this study are summarized below;

• From the structural analyses, the lowest total concrete quantity values are obtained from model 1. In addition, it is seen that the total concrete quantity values of all the building models considered do not change according to the soil class.

• The lowest total steel quantity values according to the different soil classes (Z1, Z2 and Z3) are obtained from model 5, but from model 1 with increasing axle spans. In addition, as the axle spans and the local soil class increase from Z1 to Z3, the total reinforcement (steel) quantities obtained increase. This situation shows that model 1 in the large axle spans is more economical than other building models.

• The period values of the building model with beamed slab (model 1) are less than the period values obtained from other building models. In addition, as the local soil class increase from Z1 to Z3 and axle spans increase from 5×5 m to 7×7 m, base shear force values in all models increase. On the other hand, the period values obtained by increasing the axle spans from 5×5 m to 7×7 m increase, too. This case shows that decreasing in building lateral stiffness for various reasons is subject to greater base shear forces, thereby reducing the performance of the building.

• As a result of structural analyses, the displacement values obtained from model-1 at storey levels are smaller than the other building models considered in this study. On the other hand, it is seen that as the local soil class increases from Z1 to Z3, the displacement values of all building models increase. This situation reveals one of the most important advantages of in this aspect of model-1 over other building models.

• The amount of reinforcement (steel) per square meter obtained from the building models (except for model 5) decreases with increasing axle spans. In addition, it is seen that as the local soil class in all building models increases from Z1 to Z3, steel quantity values per m^2 increase.

• As a result of the structural analysis, it is seen that the building model (model 1) having beamed slab is safer than the other building models considered when the vertical structural elements (columns) are taken into consideration. This result obtained shows that model 1 behaves better than other building models.

• It is seen that in the design of buildings to be constructed in Turkey where located in active earthquake belt is quite important in terms of the cost and safety of building of slab type when the findings of this study are examined. It is recommended that in reinforced concrete buildings to be constructed in earthquake zones use beamed slabs in terms of building safety.

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