Effects of the Design Parameters against Slab on Grade Volume Using Corps of Engineering Design Method

Muhamad Taufik Costarico, Maulid Muhammad Iqbal, Joni Arliansyah
Civil Engineering Department, Sriwijaya University, Indonesia

Abstract. Failure of concrete slab construction on the ground such as in warehouse floor, hangar floor, and rigid pavement structure on the highway may result in the inaccuracy of the applied design parameter analysis. The study aimed to analyze the effects of the design parameters of base ground material, concrete material, and vehicle load on slab on grade capacity using design method of Corps of Engineering (COE). The design parameter used vehicle loads of 25 Kips, 50 Kips, 75 kips, 100 kips and 120 Kips, medium quality concrete material of compressive strength concrete $f'c$ 20 MPa, 25 MPa, and 30 MPa as well as high quality concrete material of compressive strength concrete 35 MPa and soft base ground material (k100 Pci), medium (k 150 Pci), and hard (k 200 Pci). COE method has $f(t)$ variables, namely concrete Modulus of Rupture (flexural strength) of 485 Psi, 542 Psi, 594 Psi, vehicle axle load of 25 Kips, 50 Kips, 75 Kips, modulus of base ground reaction of k 100 Pci, 150 Pci, and 200 Pci, the number of passing vehicles of 5 million. The making of Taufik Costarico Slab On Grade (TCSOG) Program was carried out by preparing nomogram drawing digitization using autocad program, finding out the equation of lines in the excel program, and finally having it created using visual basic program. With the help of TaufikCostarico slab on grade program, there obtained 60 thicknesses of concrete slab on grade. The result of the study showed that the more the vehicle load was, the thicker the concrete plate would be. In contrast, the harder the base ground was, the thinner the concrete plate had to be. In conclusion, the high concrete quality of $f'c$ 35 MPa, hard ground of k 200 Pci, and concrete slab on grade thickness of 101.6 mm (4 in) are the same for vehicle loads of 25 kips, 50 kips, 75 kips, 100 kips and 120 kips.

1. Introduction
Failure on concrete slab construction on the ground or slab on grade such as constructions of warehouse floor, hangar floor, and rigid pavement structure of road may result from the failure in either its construction planning or implementation. The failure in planning may result from the inaccuracy of the analysis of the used design parameters, namely load parameters and material parameters. Nowadays, there have been many standards that can be used for capacity of slab on grade, among others, Method of Corps of Engineering (COE) in which each standard is developed by the experts of many institutions using various design parameters. In general, there are three main parameters in the design of slab on grade, i.e. land parameter, slab (concrete) structure material parameter, and plan load parameter. The plan design parameter depends on the authenticity of the land and ground where the slab on grade will be constructed. The working load can be either fixed load or dynamic load such as stack load, forklift load or (vehicle load) with various safety factors [1].
The magnitude of voltage, moment, and latitude, and the carrying capacity of the original ground or modulus subgrade reaction (k) affect the thickness planning of slab on grade thickness. The value of the moment rises, then the slab thickness of the floor rises. The ground elasticity modulus rises, then the moment value falls [1]. COE methods in the calculation of the thickness of slab on grade use monogram graphics which takes a long time and accuracy [2,3].

The formulation of the problem in this study was how the parameter variations of base ground material, (concrete) structural material parameter, and variation of design load affected the capacity and volume of slab on grade. The objective of the study was to analyze the effects of design parameters of base ground material, concrete material, and vehicle load on capacity of slab on grade using COE method. According ACI to calculate modulus of rupture using formula 1.1. [4,5,6]

\[
MR = 9 \sqrt{f_{c}'}
\]  

(1.1)

where:

- MR = modulus of rupture (Psi)
- \(f_{c}’\) = Compressive strength concrete (Psi)

![Figure 1. Calculation thickness Slab on Grade using Corps of Engineering Method [2,3]](image)

2. Research Methodology

This study started by determining the designs of vehicle load parameters, concrete material parameters and basic soil materials. Then a variation was made from the value of the parameter designs. There were five design variations of vehicle load, four variations of concrete quality, and three variations of modulus value of the base ground reaction. COE method has \(f(t)\) variables of concrete bending stress (MOR), vehicle load, base ground modulus, and the number of passing vehicles. The program making of Taufikcostarico slab on grade (TCSOG) was conducted by making nomogram graphic digitization using visual basic program. The calculation of each COE method was conducted by using the program of taufikcostarico slab on grade. For COE methods, 60 thicknesses of slab on grade were obtained.
After calculating the slab on grade was obtained, an analysis was conducted to find out the effects of the value variable of design parameter on the value variations of vehicle load, concrete quality, and base ground. The result of the calculation of the thickness of slab on grade was studied to find out its effects on the base ground, concrete, and vehicle load.

2.1. Variation of Design Parameter
1. The vehicle load parameter:
   a. Vehicle load of 120 Kips
   b. Vehicle load of 100 Kips
   c. Vehicle load of 75 Kips
   d. Vehicle load of 50 Kips
   e. Vehicle load of 25 Kips
The estimation of the passing vehicles on the concrete slab was 5 million times.[2]
2. Parameters of concrete and concrete quality were derived from the $f'_c$ values of 20 MPa, 25 MPa, and 30 MPa and high quality of the concrete was derived from the $f'_c$ value of 35 MPa
3. The parameters of soft, medium, and hard grounds had the values of modulus subgrade reaction 100 Pci, 150 Pci, and 200 Pci successively.

2.2. Calculation variables of thick concrete plate
1. Concrete Material
   a. Compressive Strength Concrete($f'_c$)
   MPa units were converted to be psi units by multiplying them by the factor of 0.006895. The result showed that after the conversion the concrete quality turned out to be 20 Mpa which was the same as 2900, 653 Psi, 25 MPa the same as 3625,816 Psi, 30 MPa the same as 4350,970 Psi, and 35 MPa the same as 5076,142 Psi. The Concrete Bending Strength (MR) was derived from the equation 1.1.
2. Ground Material, Modulus subgrade reaction (k) used the values of 100 Pci, 150 Pci, and 200 Pci.
3. Heavy Vehicle Load, the number of vehicles used the values of 25 Kips, 50 Kips, and 75 Kips. The number of passing vehicles was taken from the value of 5,000,000 passes.

2.3. Program of TaufikCostarico Slab On Grade
The Program of TaufikCostaricoslab on grade was created by using visual basic computer language. Steps of creating the program of taufikcostarico slab on grade
1. Digitizing of nomogram figure in AutoCAD program
   The nomogram graph of each slab on grade method was depicted in the Autocad program. It was scaled in the AutoCAD program. For parameter values that were not present in the nomogram, they were made in accordance with the existing image. The values of coordinates x and y were obtained based on the AutoCAD image.
2. Line equation in the excel program
   After the Autocad drawing was complete, the x and y coordinate points were defined. These coordinate points were included in the excel program. Then the excel graph was created and the corresponding line equation was searched.
3. Visual basic computer language
   The obtained line equation in the excel program was then made in the computer language using visual basic program.
4. The variable values that were not present in the nomogram graph were searched by interpolating. For design parameter values that did not exist in figures of nomogram graphs of 1 they were done by interpolation.
5. Calibration of program of costarico slab on grade. After the program costarico slab on grade was complete, the concrete plate thickness was calculated using COE method. The calibration of the value of concrete plate thickness resulted from the calculation of taufikcostarico program and the value of concrete plate thickness calculation with thickness value of concrete plate using nomogram graph. Then a calculation of the whole values of concrete plate thickness as many as 36 values.

3. Results and Discussion

Modulus of rupture (MOR) or flexural strenght was derived from the equation 2.1. The fc’ values of 20 MPa, 25 MPa, 30 Mpa, and 35 MPa produced the MOR values of 485 Psi, 542 Psi, 594 Psi, and 641 Psi.

3.1. Program of Taufik Costarico Slab on Grade

The program of Taufik Costarico Slab on Grade (TCSOG) is an application for calculating the concrete plate thickness using the standard method of COE created using visual basic computer language. The initial view of TCSOG is given in figure 2. In this view there are choices of methods to be used for calculating concrete plate, i.e. COE, PCA, and WRI.

![Figure 2. Display of TCSOG Program COE Method](image)

The tool bar shows file, option, and about. The menu option has choices of COE, PCA, WRI, nomogram, and function database. Nomogram graph shows figures of nomogram graphs to be used to create the program of TCSOG. The function database is used for the formula of line equation. Calculation of concrete bending strength or flexural strength, value of base ground reaction modulus (k), vehicle load, the number of passing vehicles, and concrete plate thickness. The calculation variables are shown in Table 1. Inputting the values of pressing variables results in the value of T(in) and it can be saved by pressing the save button such as shown in figure 3. Choose method COE so that figure 2 will be display. The result of the smallest concrete plate thickness with the identity of TC 100 20 25, having the concrete plate thickness derived from the program of TCSOG 7.69 in based on figure 3 and graph 7.7 in based on figure 1. The difference of the calculation results of concrete plate thickness between TCSOG program and graph was 0.01 in or 0.254 mm.
The calculation of Slab on Grade thickness was carried out by the help of software program of TCSOG by inputting the values of vehicle load design parameters, concrete material, and base ground. After obtaining the values of concrete plate thickness in inches, they were then converted into units of mm.

First input flexural strength was 485 psi and then input axle load was 25 kips and then modulus subgrade reaction was 100 pound cubic inch and then input vehicle passes $5 \times 10^6$ and then choose save result calculation file. The result calculation was 7.69 inch. See figure 3.

Table 1. Results Thickness and cost of concrete Slab on Grade using Program TCSOG on soft soil

| Parameter Design | Method | COE | Unit Price | $\Sigma$ cost | $\Delta$ cost |
|------------------|--------|-----|------------|--------------|--------------|
| PCi K Fe' | Load | Thickness | Concrete/m$^3$ | (Rp) | (Rp) | (Rp) |
| Load 120 Kips | 100 | 35 | 120 | 466.34 | 2.31E+06 | 1.08E+06 | -3.95E+04 |
| | 100 | 30 | 120 | 492.00 | 2.27E+06 | 1.12E+06 | -2.82E+04 |
| | 100 | 25 | 120 | 508.00 | 2.26E+06 | 1.15E+06 | 4.21E+04 |
| Load 100 Kips | 100 | 35 | 100 | 409.96 | 2.31E+06 | 9.49E+05 | -3.66E+04 |
| | 100 | 30 | 100 | 433.32 | 2.27E+06 | 9.85E+05 | -5.73E+04 |
| | 100 | 25 | 100 | 461.77 | 2.26E+06 | 1.04E+06 | 3.85E+04 |
| Load 75 Kips | 100 | 35 | 75 | 330.96 | 2.31E+06 | 7.66E+05 | -2.53E+04 |
| | 100 | 30 | 75 | 347.88 | 2.27E+06 | 7.91E+05 | -4.20E+04 |
| | 100 | 25 | 75 | 369.06 | 2.26E+06 | 8.33E+05 | -2.74E+04 |
| Load 50 Kips | 100 | 35 | 50 | 255.27 | 2.31E+06 | 5.91E+05 | -2.03E+04 |
| | 100 | 30 | 50 | 268.73 | 2.27E+06 | 6.11E+05 | -3.30E+04 |
| | 100 | 25 | 50 | 285.24 | 2.26E+06 | 6.44E+05 | -2.22E+04 |
| Load 25 Kips | 100 | 35 | 25 | 161.29 | 2.31E+06 | 3.73E+05 | -1.43E+04 |
| | 100 | 30 | 25 | 170.43 | 2.27E+06 | 3.88E+05 | -2.31E+04 |
| | 100 | 25 | 25 | 181.86 | 2.26E+06 | 4.11E+05 | -1.42E+04 |
| | 100 | 20 | 25 | 195.33 | 2.18E+06 | 4.25E+05 | -
Slab on Grade assumed area 1 m² and unit price concrete per cubic meter [7]. The result calculation thickness slab on grade and difference cost see table 1, 2, and 3. The calculation of the concrete plate thickness by the COE method with the number of passing vehicles was 5,000,000 (five million), see section 1. According to figure 1 the minimum requirement of concrete plate thickness was 4 in. The values of concrete plate derived from the calculation result which was less than 4 in (<4 in) was corrected into 4 in. For the whole calculation result, see Table 1.

The maximum value of concrete plate thickness derived from the calculation using the COE method was 508 mm obtained in the identity of TC 100 20 120 and TC 100 25 120. On soft ground, the minimum value of concrete plate thickness was 6.35 in (161.29 mm) in the identity of TC 100 35 25. In the table 1 load 120 Kips difference compressive strength 20 Mega Pascal to 25 Mega Pascal was difference cost Rupiah 42,100 more expensive than compressive strength 20 Mega Pascal because thickness slab on grade were same. For different compressive strength 30 Mega Pascal to 25 Mega Pascal difference cost were Rupiah 28,200 cheaper than compressive strength 25 Mega Pascal. For different compressive strength 35 Mega Pascal to 30 Mega Pascal difference cost were Rupiah 39,500 cheaper than compressive strength 30 Mega Pascal.

As the way same different compressive strength look table 1 for load 100 kips, 75 kips, 50 kips and 25 kips on soft soil. For the whole calculation result, see Table 1.

**Table 2. Results Thickness and cost of concrete Slab on Grade using Program TCSOG on medium soil**

| Parameter Design Variation | Method | COE | Unit Price | Σcost | Δcost |
|----------------------------|--------|-----|------------|-------|-------|
| K  |  Fc' | Load | Tickness | Concrete/m³ | (Rp) | (Rp) | (Rp) | (Rp) |
| PCI | MPa | Kips | mm | | | | | |
| Load 120 Kips | 150 | 35 | 120 | 442.98 | 2,31E+06 | 1,03E+06 | -1,14E+05 |
| | 150 | 30 | 120 | 501.14 | 2,27E+06 | 1,14E+06 | 8,03E+03 |
| | 150 | 25 | 120 | 501.14 | 2,26E+06 | 1,13E+06 | 2,66E+04 |
| | 150 | 20 | 120 | 508.00 | 2,18E+06 | 1,10E+06 | |
| Load 100 Kips | 150 | 35 | 100 | 389.64 | 2,31E+06 | 9,02E+05 | -3,68E+04 |
| | 150 | 30 | 100 | 412.75 | 2,27E+06 | 9,39E+05 | -5,76E+04 |
| | 150 | 25 | 100 | 441.20 | 2,26E+06 | 9,96E+05 | -4,02E+04 |
| | 150 | 20 | 100 | 476.50 | 2,18E+06 | 1,04E+06 | |
| Load 75 Kips | 150 | 35 | 75 | 315.47 | 2,31E+06 | 7,30E+05 | -2,59E+04 |
| | 150 | 30 | 75 | 332.49 | 2,27E+06 | 7,56E+05 | -4,40E+04 |
| | 150 | 25 | 75 | 354.33 | 2,26E+06 | 8,00E+05 | -2,75E+04 |
| | 150 | 20 | 75 | 380.49 | 2,18E+06 | 8,28E+05 | |
| Load 50 Kips | 150 | 35 | 50 | 243.33 | 2,31E+06 | 5,63E+05 | -2,08E+04 |
| | 150 | 30 | 50 | 256.79 | 2,27E+06 | 5,84E+05 | -3,32E+04 |
| | 150 | 25 | 50 | 273.30 | 2,26E+06 | 6,17E+05 | -2,32E+04 |
| | 150 | 20 | 50 | 294.39 | 2,18E+06 | 6,40E+05 | |
| Load 25 Kips | 150 | 35 | 25 | 153.16 | 2,31E+06 | 3,54E+05 | -1,46E+04 |
| | 150 | 30 | 25 | 162.31 | 2,27E+06 | 3,69E+05 | -2,32E+04 |
| | 150 | 25 | 25 | 173.74 | 2,26E+06 | 3,92E+05 | -1,54E+04 |
| | 150 | 20 | 25 | 187.45 | 2,18E+06 | 4,08E+05 | |

On medium ground the minimum value of the concrete plate thickness was 6.03 in (153.162 mm) in the identity of TC 150 35 25 and the maximum value was 508 mm in the identity of TC 150 20 120. In the table 2 load 120 Kips difference compressive strength 20 Mega Pascal to 25 Mega Pascal was difference cost Rupiah 26,600 more expensive than compressive strength 20 Mega Pascal because thickness slab on grade were almost the same. For different compressive strength 30 Mega Pascal to 25 Mega Pascal difference cost were Rupiah 8,030 more expensive than compressive strength 25 Mega Pascal. For different compressive strength 35 Mega Pascal to 30 Mega Pascal difference cost were Rupiah 39,500 cheaper than compressive strength 30 Mega Pascal.
Mega Pascal to 30 Mega Pascal difference cost were Rupiah 114,000 cheaper than compressive strength 30 Mega Pascal.

As the way same different compressive strength look table 2 for load 100 kips, 75 kips, 50 kips and 25 kips on soft soil For the whole calculation result, see Table 2

**Table 3.** Results Thickness and cost of concrete Slab on Grade using Program TCSOG on hard soil

| Parameter Design | Method | COE | Unit Price | Σcost | Δcost |
|------------------|--------|-----|------------|-------|-------|
| Parameter Design Variation | K | Fc' | Load | Thickness | Concrete/m³ | (Rp) | (Rp) | (Rp) |
| Load 120 Kips | 200 | 35 | 120 | 101,60 | 2,31E+06 | 2,35E+05 | -1,76E+05 |
| 200 | 30 | 120 | 180,59 | 2,27E+06 | 4,11E+05 | -2,14E+05 |
| 200 | 25 | 120 | 276,86 | 2,26E+06 | 6,25E+05 | -1,88E+05 |
| 200 | 20 | 120 | 373,63 | 2,18E+06 | 8,13E+05 | -1,88E+05 |
| Load 100 Kips | 200 | 35 | 100 | 101,60 | 2,31E+06 | 2,35E+05 | -1,17E+05 |
| 200 | 30 | 100 | 154,94 | 2,27E+06 | 3,52E+05 | -1,90E+05 |
| 200 | 25 | 100 | 240,28 | 2,26E+06 | 5,43E+05 | -1,68E+05 |
| 200 | 20 | 100 | 326,90 | 2,18E+06 | 7,11E+05 | -1,68E+05 |
| Load 75 Kips | 200 | 35 | 75 | 101,60 | 2,31E+06 | 2,35E+05 | -8,37E+04 |
| 200 | 30 | 75 | 140,21 | 2,27E+06 | 3,19E+05 | -1,42E+05 |
| 200 | 25 | 75 | 203,96 | 2,26E+06 | 4,61E+05 | -1,24E+05 |
| 200 | 20 | 75 | 268,73 | 2,18E+06 | 5,84E+05 | -1,24E+05 |
| Load 50 Kips | 200 | 35 | 50 | 101,60 | 2,31E+06 | 2,35E+05 | -4,56E+03 |
| 200 | 30 | 50 | 105,41 | 2,27E+06 | 2,40E+05 | -1,11E+05 |
| 200 | 25 | 50 | 155,45 | 2,26E+06 | 3,51E+05 | -9,87E+04 |
| 200 | 20 | 50 | 206,76 | 2,18E+06 | 4,50E+05 | -9,87E+04 |
| Load 25 Kips | 200 | 35 | 25 | 101,60 | 2,31E+06 | 2,35E+05 | 4,11E+03 |
| 200 | 30 | 25 | 101,60 | 2,27E+06 | 2,31E+05 | 1,63E+03 |
| 200 | 25 | 25 | 101,60 | 2,26E+06 | 2,29E+05 | 5,07E+03 |
| 200 | 20 | 25 | 128,78 | 2,18E+06 | 2,80E+05 | 5,07E+03 |

On hard ground the maximum value was 373,63 mm in the identity of TC 200 20 120. In the table 3 load 120 Kips difference compressive strength 20 Mega Pascal to 25 Mega Pascal was difference cost Rupiah 188,000 cheaper than compressive strength 20 Mega Pascal For different compressive strength 30 Mega Pascal to 25 Mega Pascal difference cost were Rupiah 214000 cheaper than compressive strength 25 Mega Pascal For different compressive strength 35 Mega Pascal to 30 Mega Pascal difference cost were Rupiah 176,000 cheaper than compressive strength 30 Mega Pascal.

As the way same different compressive strength look table 3 for load 100 kips, 75 kips, 50 kips and 25 kips on soft soil For the whole calculation result, see Table 3.

Figure 4 showed that the greater the concrete quality value was, the smaller the concrete plate value became. Figure 4 shows that the more the vehicle load was, the thicker the concrete plate would be. In figure 4 for concrete quality of 20 MPa the max value of concrete plate derived from the calculation was 508 mm in the identity of TC 100 20 120. For concrete quality of 25 MPa the maximum value of plate thickness was 508 mm in the identity of TC 100 25 120. For concrete quality of 30 MPa the maximum value of plate thickness was 492 mm in the identity of TC 100 30 120. For concrete quality of 35 MPa the maximum value of plate thickness was 466,34 mm in the identity of TC 100 35 120. In figure 4, the concrete quality of 20 MPa on soft ground increased the load of 25-50-75-100-120 Kips in which the concrete plate thickness increased to $\Delta T$ of 111 mm, $\Delta T$ of 89.41 mm, $\Delta T$ of 101.35 mm and $\Delta T$ of 10.92 mm.

In figure 4, the concrete quality of 25 MPa on soft ground increased the load of 25-50-75 Kips in which the concrete plate thickness increased to $\Delta T$ of 103.38 mm, $\Delta T$ of 83.82 mm, $\Delta T$ of 92.71 mm.
mand ΔT of 46.23 mm. In figure 4, the concrete quality of 30 MPa on soft ground increased the load of 25-50-75 Kips in which the concrete plate thickness increased to ΔT of 98.30 mm, ΔT of 79.25 mm, ΔT of 144.02 mm. In figure 4 the concrete quality of 35 MPa on soft ground increased the load of 25-50-75 Kips in which the concrete plate thickness increased to ΔT of 93.98 mm, ΔT of 75.69 mm, ΔT of 78.99 mm and ΔT of 56.39 mm.

**Figure 4.** Thickness Slab on Grade against variable fc´ with variety vehicle load on soft soil

Figure 5 showed that the greater the concrete quality value was, the smaller the concrete plate value became. Figure 5 shows that the more the vehicle load was, the thicker the concrete plate would be. In figure 5 for concrete quality of 20 MPa the max value of concrete plate derived from the calculation was 508 mm in the identity of TC 15 20 120. For concrete quality of 25 MPa the maximum value of plate thickness was 501.14 mm in the identity of TC 15 25 120. For concrete quality of 30 MPa the maximum value of plate thickness was 501.14 mm in the identity of TC 15 30 120. For concrete quality of 35 MPa the maximum value of plate thickness was 442.98 mm in the identity of TC 15 35 120. In figure 4, the concrete quality of 20 MPa on medium ground increased the load of 25-50-75-100-120 Kips in which the concrete plate thickness increased to ΔT of 106.93 mm, ΔT of 86.11 mm, ΔT of 96.01 mm and ΔT of 31.50 mm.

In figure 5, the concrete quality of 25 MPa on medium ground increased the load of 25-50-75 Kips in which the concrete plate thickness increased to ΔT of 99.57 mm, ΔT of 86.87 mm and ΔT of 59.94 mm. In figure 5, the concrete quality of 30 MPa on medium ground increased the load of 25-50-75 Kips in which the concrete plate thickness increased to ΔT of 94.50 mm, ΔT of 75.70 mm, ΔT of 80.27 mm and ΔT of 168.66 mm. In figure 4 the concrete quality of 35 MPa on medium ground increased the load of 25-50-75 Kips in which the concrete plate thickness increased to ΔT of 90.17 mm, ΔT of 72.14 mm, ΔT of 74.17 mm and ΔT of 53.34 mm.

![Figure 4: Thickness Slab on Grade against variable fc with variety vehicle load on soft soil](image-url)
Figure 6 showed that the greater the concrete quality value was, the smaller the concrete plate value became. Figure 4 shows that the more the vehicle load was, the thicker the concrete plate would be. In figure 6 for concrete quality of 20 MPa the max value of concrete plate derived from the calculation was 373.63 mm in the identity of TC 200 20 120. For concrete quality of 25 MPa the maximum value of plate thickness was 276.86 mm in the identity of TC 200 25 120. For concrete quality of 30 MPa the maximum value of plate thickness was 180.59 mm in the identity of TC 200 30 120. For concrete quality of 35 MPa the maximum value of plate thickness was 101.60 mm in the identity of TC 200 35 120. In figure 6, the concrete quality of 20 MPa on hard ground increased the load of 25-50-75-120 Kips in which the concrete plate thickness increased to $\Delta T$ of 77.98 mm, $\Delta T$ of 61.98 mm, $\Delta T$ of 58.17 mm and $\Delta T$ of 46.74 mm.

In figure 6, the concrete quality of 25 MPa on hard ground increased the load of 25-50-75 Kips in which the concrete plate thickness increased to $\Delta T$ of 53.85 mm, $\Delta T$ of 48.51 mm, $\Delta T$ of 36.32 mm and $\Delta T$ of 36.58 mm. In figure 6, the concrete quality of 30 MPa on hard ground increased the load of 25-50-75 Kips in which the concrete plate thickness increased to $\Delta T$ of 3.81 mm, $\Delta T$ of 34.80 mm, $\Delta T$ of 14.73 mm and $\Delta T$ of 40.38 mm. In figure 6 the concrete quality of 35 MPa on hard ground increased the load of 25-50-75 Kips in which the concrete plate thickness increased to $\Delta T$ of 0 mm, $\Delta T$ of 0 mm, $\Delta T$ of 0 mm and $\Delta T$ of 0 mm. The value of base ground Modulus of 200 Pci for loads of 25 Kips, 50 Kips, and 75 Kips with the concrete quality of fc 35 MPa it is the same as that of 101.60 mm.

![Figure 5. Thickness Slab on Grade against variable fc' with variety vehicle load on medium soil](image-url)
Figure 6. Thickness Slab on Grade against variable $f_{c'}$ with variety vehicle load on hard soil

4. Conclusion

The COE method is concluded as follows: the value of base ground Modulus of 200 Pci for loads of 25 Kips, 50 Kips, and 75 Kips with the concrete quality of $f_{c}$ 35 MPa it is the same as that of 101.60 mm. It is suggested for further research that using the vehicle loads of 5 tons, 8 tons, 10 tons, 20 tons, and 19 tons be in accordance with the regulations applicable in the Republic of Indonesia.

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