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# Experimental Study on Design of Flexible Pavement Using CBR Method

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***Abstract:* *As per IRC recommendation, California Bearing Ratio (CBR) value of sub grade is used for design of flexible pavements. California Bearing Ratio (CBR) value is an important soil parameter for design of flexible pavements. CBR value of soil may depend on many factors like maximum dry density (MDD), Optimum moisture content (OMC), Liquid limit (LL), Plastic limit (PL), Plasticity index (PI), Type of soil, etc..And also CBR value of the soil is affected by the soaked and unsoaked condition of the soil, the results obtained by these tests are used with the empirical curves determined the thickness of pavement and it's component layers. Sub grade soil is an essential component for design of both flexible and rigid pavement structure, laboratory investigation of sub grade strength parameter as CBR beneficial for design of flexible pavement. This study considers the use of CBR, Unconfined compressive strength (UCS). In this paper the attempts have been made to seek the value of CBR of soil sample, soil sample allowing with fly ash.***

**Keywords:** California Bearing Ratio, fly ash, soaked condition, flexible pavement.

## 1. Introduction

In 1928 California Division of Highway in the U.S.A. developed CBR method for pavement design. The majority of design curves developed later are based on the original curves propped by O.J.Porter. California bearing ratio (CBR) is an empirical test and widely applied in design of flexible pavement over the world. This method was developed during 1928-29 by the California Highway Department. Use of CBR test results for design of roads, introduced in USA during 2nd World War and subsequently adopted as a standard method of design in other parts of the world, is recently being discouraged in some advanced countries because of the imperialness of the method (Brown, 1996). The California bearing ratio (CBR) test is frequently used in the assessment of granular materials in base, subbase and subgrade layers of road and airfield pavements. The CBR test was originally developed by the California State Highway Department and was thereafter incorporated by the Army Corps of Engineers for the design of flexible pavements. It has become so globally popular that it is incorporated in many international standards ASTM 2000. The significance of the CBR test emerged from the following two facts, for almost all pavement design charts, unbound materials are basically characterized in terms of their CBR values when they are compacted in pavement layers and the CBR value has been correlated with some fundamental properties of soils, such as plasticity indices, grain-size distribution, bearing capacity, modulus of subgrade reaction, modulus of resilience, shear strength, density, and molding moisture content Doshi and Guirguis 1983 Because these correlations are currently readily available to the practicing engineers who have gained wide experience with them, the CBR test remains a popular one.

Most of the Indian highways system consists of flexible pavement; there are different methods of design of flexible pavement. The California Bearing Ratio (CBR) test is an empirical method of design of flexible pavement design. It is a load test applied to the surface and used in soil investigations as an aid to the design of pavements. The design for new construction should be based on the strength of the samples prepared at optimum moisture content (OMC) corresponding to the Proctor Compaction and soaked in water for a period of four days before testing. In case of existing road requiring strengthening, the soil should be moulded at the field moisture content and soaked for four days before testing. It has been reported that, soaking for four days may be very severe and may be discarded in some cases, Bindra 1991. This test method is used to evaluate the potential strength of subgrade, subbase, and base course material for use in road and airfield pavements. Bindra 1991 reported that design curves (based on the curve evolved by Road Research Laboratory, U.K) are adopted by Indian Road Congress (IRC: 37-1970). As per IRC, CBR test should be performed on remoulded soil in the laboratory. In-situ tests are not recommended for design purpose Bindra, 1991. The design of the pavement layers to be laid over subgrade soil starts off with the estimation of subgrade strength and the volume of traffic to be carried. The Indian Road Congress (IRC) encodes the exact design strategies of the pavement layers based upon the subgrade strength which is most commonly expressed in terms of the California Bearing Ratio (CBR). For the design of pavement CBR value is invariably considered as one of the important parameter. With the CBR value of the soil known, the appropriate thickness of construction required above the soil for different traffic conditions is determined using the design charts, proposed by IRC. CBR value can be measured directly in the laboratory test in accordance with IS:2720 (Part-XVI) on soil sample procured from the work site. Laboratory test takes at least 4 days to measure the CBR value for each soil sample under soaked condition. In addition, the test requires large quantity of the soil sample and the test requires skill and experience without which the results may be inaccurate and misleading.

## 2. Experimental program

For checking the properties of the soil, reported different properties like Grain Size Analysis, maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI), etc.

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**Materials and Methodology**

Loose red earth was obtained from Sree Vidyanikethan Engineering College in Parking place Tirupati, soil Sample were collected at a depth of 1 meter, soil passing 4.75 mm sieve is used in tests, all tests are conducted based on IS: 2720 - part 4 and The material which is collected for testing is different in quality and property, so that the material was separately tested in the laboratory so as to design the soil sub grade.

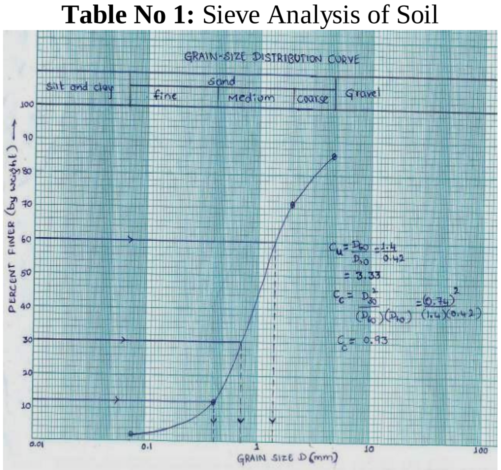
**Sieve analysis**

Grain size analysis is carried out to determine the relative percentages of different sizes of particles in the sample. These sizes control the mechanical behavior of coarse grained soil. Dry method of sieving is used for coarser fractions (retained on 4.75 mm sieve) and wet method is used for finer fractions (retained on 75micron sieve) and pipette method is used for fractions passing 75 micron sieve.

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for to determine suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used. Weight of Dry Sample: 1000 gms

| IS Sieve Size (mm) | Weight Retained (gm) | Percentage Weight Retained (gm) | Cumulative Percentage Retained (%) | Cumulative Percentage finer (%) |
|---|---|---|---|---|
| 100 | - | - | 0 | 100 |
| 75 | - | - | 0 | 100 |
| 19 | - | - | 0 | 100 |
| 4.75 | 140.3 | 14.03 | 14.03 | 85.97 |
| 2 | 144.4 | 14.44 | 28.47 | 71.53 |
| 0.425 | 588.9 | 58.89 | 87.36 | 12.64 |
| 0.075 | 107.4 | 10.74 | 98.1 | 1.9 |
| Pan | 19 | 1.9 | 100 | 0 |

**Table No 1:** Sieve Analysis of Soil




**Graph 1: Sieve analysis Test curve**

**Summary of Results**

Percentage of Gravel in soil sample = Nil

**Liquid Limit,Plastic Limit and Plasticity Index (IS 2720-Part 5)**

**Purpose**

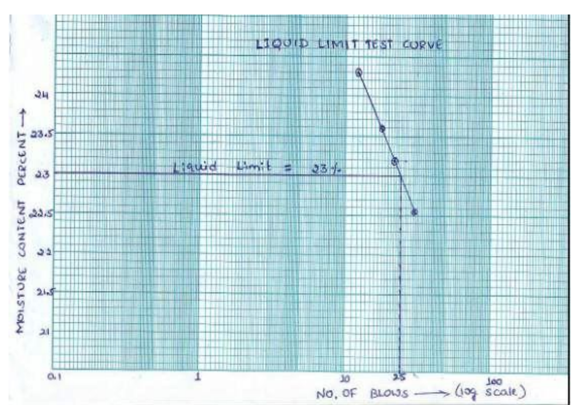
The Liquid and Plastic Limits (Atterberg Limits) of soil indicate the water contents at which certain changes in the physical behavior of soil can be observed. From Atterberg limits, it is possible to estimate the engineering properties of fine-grained soils. Plasticity is the property that enables a material to undergo deformation without noticeable elastic recovery and without cracking or crumbling. Plasticity is a major characteristic of soils containing an appreciable proportion of clay particles.

**Figure1:** Liquid Limit Device.

**Atterberg Limits Test Determination of Liquid Limit (LL):**

| S.No | Determination No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 1 | No. of blows | 30 | 27 | 18 | 12 |
| 2 | Container No. | 46 | 47 | 48 | 49 |
| 3 | Wt. of container (W1) gm | 16.75 | 16.35 | 18.90 | 17.84 |
| 4 | Weight of container + wet soil (W2) | 27.29 | 21.39 | 29.50 | 23.25 |
| 5 | Weight of container + dry soil (W3) | 25.35 | 20.44 | 27.47 | 22.19 |
| 6 | Loss of Moisture (gm) | 1.94 | 0.95 | 2.03 | 1.06 |
| 7 | Wt. of dry soil (gm) | 8.6 | 4.09 | 8.57 | 4.35 |
| 8 | Moisture content % | 22.55 | 23.22 | 23.68 | 24.36 |

**Table 2:** Determination of Liquid Limit (LL).




**Graph 2:** Liquid limit test Curve.

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Result: Moisture content at 25 blows from the graph.
Liquid Limit (LL) = 23%

**Determination of Plastic Limit (PL)**

| S.No | Determination No. | 1 | 2 | 3 |
|---|---|---|---|---|
| 1 | Container Number | 51 | 52 | 53 |
| 2 | Weight of container + wet soil (gm) | 20.23 | 17.10 | 19.23 |
| 3 | Weight of container + dry soil (gm) | 20.10 | 17.02 | 19.20 |
| 4 | Loss of Moisture (gm) | 0.13 | 0.08 | 0.03 |
| 5 | Wt. of container (gm) | 19.42 | 16.63 | 18.94 |
| 6 | Wt. of dry soil (gm) | 0.68 | 0.39 | 0.26 |
| 7 | Moisture content % | 19.1 | 20.5 | 11.53 |

**Table 3:** Determination of Plastic Limit (PL)

Plastic Limit (PL) = 17.04 %

Plasticity Index (Pl) = LL - PL = 23 − 17.40 = 5.6%

**Proctor Density (IS: 2720 - Part 7)**

Compaction is the process of densification of soil mass by reducing air voids. The purpose of laboratory compaction test is so determine the proper amount of water at which the weight of the soil grains in a unit volume of the compacted is maximum, the amount of water is thus called the Optimum Moisture Content (OMC). In the laboratory different values of moisture contents and the resulting dry densities, obtained after compaction are plotted both to arithmetic scale, the former as abscissa and the latter as ordinate. The points thus obtained are joined together as a curve. The maximum dry density and the corresponding OMC are read from the curve.

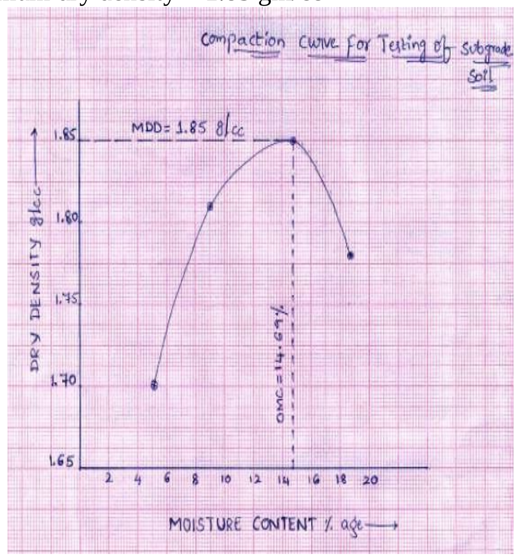
**CALCULATION**

1. Description of Sample = Sandy Clay-Sandy Silt (SC-SM)
2. Weight of Mould = 4250 gm
3. Volume of Mould = 1000 cc

| S.No | Determination No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 1 | Weight of Mould + Compacted soil (gm) | 6041 | 6232 | 6380 | 6370 |
| 2 | Weight of Compacted soil (gm) | 1791 | 1982 | 2130 | 2120 |
| 3 | Wet Density γt=wt/v (gm/cc) | 1.791 | 1.982 | 2.130 | 2.120 |
| 4 | container no | A1 | A2 | A3 | A4 |
| 5 | Weight of container + wet Soil (gm) | 46.34 | 44.80 | 50.21 | 50.99 |
| 6 | Weight of container + Dry soil (gm) | 40.46 | 39.85 | 46.41 | 45.79 |
| 7 | Weight of water (gm) | 1.1 | 2.04 | 3.8 | 5.2 |
| 8 | Weight of container (gm) | 18.98 | 17.39 | 20.55 | 17.92 |
| 9 | Weight of dry soil (gm) | 21.48 | 22.46 | 25.86 | 27.87 |
| 10 | Water content (%) | 5.12 | 9.08 | 14.69 | 18.65 |
| 11 | Dry Density(gm/cc) γd=γt/1+w | 1.704 | 1.817 | 1.85 | 1.786 |

**Table 4:** Data Sheet for Proctor Compaction Test.

Results: (As per Graph Below)
1. Optimum moisture content = 14.69 %
2. Maximum dry density = 1.85 gm/cc




**Graph 3:** Proctor compaction test curve.

**The California Bearing Ratio Test (IS: 2720 - Part 16)**
**Need and Scope**

The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. California bearing ratio is the ratio of force per unit area required to penetrate in to a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm / min. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

Figure 2: CBR testing of different Soil Samples.

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**CALCULATION**

1. Sample = Sandy Clay-Sandy Silt (SC-SM)
2. Source of material =Sree Vidyanikethan Engineering college

Note:

I Represents Soil +5% Fly ash
III Represents Soil +10% Fly ash
III Represents Soil +15% Fly ash

**Results**

**Only Soil**

2.5 mm Penetration CBR = Test load/ Standard load × 100% = (53.5/1370) × 100 = 3.9%
5 mm Penetration CBR = Test load/ Standard load × 100% = (81.6/2055) × 100 = 3.97%

**Case-I**

2.5 mm Penetration CBR = Test load/ Standard load × 100% = (57.6/1370) × 100 = 4.20%
5 mm Penetration CBR = Test load/ Standard load × 100% = (62.7/2055) × 100 = 3.05%

**Traffic Design:** The recommended method considers design traffic in terms of the cumulative number of standard axles to be carried by the pavements during the design life. Axle load spectrum data are required where cementations bases are used for evaluating the fatigue damage of such bases for heavy traffic.

**Calculation of Pavement Thicknesses:**

Available Data:

1. Design of CBR of Subgrade Soil: 3.97%
2. Design Life of Pavement: 10 years
3. Annual Growth rate: 5 %
4. Distribution of Commercial vehicle for Single Lane: Single Lane
5. Computation of Design traffic for the end of Design life: 0.75

**Computation of Design Traffic**

The design traffic in terms of the cumulative number of standard axles to be carried during the design life of the road should be computed using the following equation:

$$N = \{365\times[(1+r)^{n}-1]/r\}\times\{A\times D\times F)\}$$

N = The cumulative no. of standard axles to be catered for in the design in terms of msa.

A = Initial Traffic in the year of completion of completion of construction in terms of the number of Commercial Vehicle Per Day(CVPD)

**Case-I** Soil + 5 % Fly ash-Total pavement thickness = 711 mm

Pavement composition interpolated as per MORT&H (IRC37-2012 page 26 plate 2)

**Case-II**

2.5 mm Penetration CBR = Test load/ Standard load × 100% = (71.4/1370) × 100 = 5.2%
5 mm Penetration CBR = Test load/ Standard load × 100% = (87.7/2055) × 100 = 4.26%

**Case-III**

2.5 mm Penetration CBR = Test load/ Standard load × 100% = (42.8/1370) × 100 = 3.12%
5 mm Penetration CBR = Test load/ Standard load × 100% = (63.2/2055) × 100 = 3.07%

**CBR Value for subgrade soil = 3.97%**
**CBR Value for subgrade soil + 5% Fly ash =4.20%**
**CBR Value for subgrade soil + 10% Fly ash =5.2%**
**CBR Value for subgrade soil + 15% Fly ash =3.12%**

**Traffic volume count survey:**

Commercial Vehicle per day = 800 nos

$$A = P\,(1+r)^{x}$$

P = No. of commercial vehicles as per last count
x = No. of years between the last count and the year of completion of construction
D = Lane distribution factor
F = Vehicle damage factor
n = Design Life in Years
r = Annual growth rate of commercial vehicles

**Design Calculation of Pavement thickness:**

1. Commercial Vehicle at last count "P" =800CV/Day
2. r =5%
3. x =1
4. A =840
5. D =1
6. F =3.5

7. N = 13.9 msa (say 14 msa)

8. Total thickness of pavement for design CBR 3.97%

For 3.97% design traffic 14 msa of IRC37, 2001 Total Thickness = 711mm

9. Pavement composition interpolated as per MORT&H (IRC37-2012 page 26 plate 2)

(a) Granular Sub base = 330 mm

(b) Base course (wmm) = 250 mm

(c) DBM =91 mm

(d) BC =40 mm

| S.No | Description | Layers | Layers Thickness |
|---|---|---|---|
| 1 | | Granular Sub base | 330 |
| 2 | | Base Coarse (WMM) | 250 |

| | | | |
|---|---|---|---|
| 3 | Soil + 5% fly ash | DBM | 91 |
| 4 | | BC | 40 |

**Case-II** Soil + 10 % Fly ash- Total pavement thickness = 671mm

Pavement composition interpolated as per MORT&H (IRC37-2012 page 26 plate 3)

| S.No | Description | Layers | Layers Thickness |
|---|---|---|---|
| 1 | Soil + | Granular Sub base | 300 |
| 2 | | Base Coarse (WMM) | 250 |
| 3 | | DBM | 81 |
| 4 | 10% fly ash | BC | 40 |

**Case-III** Soil + 15 % Fly ash- Total pavement thickness = 771mm

Pavement composition interpolated as per MORT&H (IRC37-2012 page 26 plate 1)

| Sl.No | Description | Layers | Layers Thickness |
|---|---|---|---|
| 1 | Soil + 15% fly ash | Granular Sub base | 380 |
| 2 | | Base Coarse (WMM) | 250 |
| 3 | | DBM | 101 |
| 4 | | BC | 40 |

### 3. Conclusions

The major conclusions drawn at the end of this work are as follows:

1. The thickness of pavement varies with the change in the value of C.B.R. With higher value of C.B.R. the pavement thickness is less and vice versa.
2. From these experimental results it has been observed that the soil SC-SM with 10% fly ash is suitable for the construction purpose for soil subgrade in comparison with only soil, soil with 5% fly ash and soil with 15% fly ash on the basis of higher values of CBR.
3. Due to the saving in Pavement thickness is less quantity of material will be applicable so that, huge amount of money can be saved.
4. Due to the higher value of CBR for 10% fly ash with soil will be more durable compared to 5% and 15% of fly ash with soil and also with only soil.
5. Further this Research work can be carried with different materials to improve CBR values and also with different Soaking Conditions.

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Table 5: Data Sheet for CBR Test.

| **Penetration in mm** | **Proving ring Reading No. Divisions** | | | | **Test load/Corrected load 2 × Value of One division in (kg)** | | | | **Standard load in (kg) on Plunger area 19.64 cm2** | **Soaked CBR % 3/4× 100** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **2** | | | | **3** | | | | **4** | **5** | | | |
| | Only Soil | I | II | III | Only soil | I | II | III | | Only soil | I | II | III |
| 0.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| 0.5 | 6.5 | 7 | 4 | 2.9 | 33.15 | 35.7 | 20.4 | 15 | | | | | |
| 1.0 | 7.5 | 8 | 6.2 | 6 | 38.25 | 40.8 | 31.62 | 30.6 | | | | | |
| 1.5 | 9 | 9 | 8 | 7 | 45.9 | 45.9 | 40.8 | 35.7 | | | | | |
| 2 | 9.8 | 10 | 12 | 7.8 | 50 | 51 | 61.2 | 40 | | | | | |
| 2.5 | **10.5** | **11.3** | **14** | **8.4** | **53.5** | **57.6** | **71.4** | **42.8** | **1370** | **3.90** | **4.20** | **5.21** | **3.12** |
| 3 | 11.7 | 11.5 | 14.5 | 9.0 | 60 | 59 | 74 | 46 | | | | | |
| 3.5 | 12.6 | 11.7 | 15.2 | 9.6 | 64.5 | 60 | 78 | 49 | | | | | |
| 4 | 13.7 | 11.9 | 15.8 | 10.3 | 70 | 61 | 81 | 53 | | | | | |
| 4.5 | 14.9 | 12.1 | 16.4 | 11.1 | 76 | 62 | 84 | 57.1 | | | | | |
| 5 | **16** | **12.3** | **17.2** | **12.4** | **81.6** | **62.7** | **87.7** | **63.2** | **2055** | **3.97** | **3.05** | **4.26** | **3.07** |
| 5.5 | 17.4 | 12.3 | | 11.9 | 89 | 62.7 | | 61 | | | | | |
| 6 | 18.8 | 12.3 | | 12 | 96 | 62.7 | | | | | | | |
| 6.5 | 21 | 12.3 | | | 107.1 | 62.7 | | | | | | | |
| 7 | 23.5 | 12.4 | | | 120 | 63.2 | | | | | | | |
| 7.5 | 26 | 12.4 | | | 132.6 | 63.2 | | | | | | | |

Table 6: Traffic Volume Survey for Pavement

| Time | HVC Bus/Truck | | | Scooter/Motor cycle | | | Cars/Agricultural Tractor | | | Hand cart/ Bullock cart | | | Heavy weight vehicles | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.00 to 8.00 AM | 14 | 15 | 6 | 39 | 50 | 28 | 16 | 16 | 18 | 2 | 0 | 2 | 0 | 2 | 0 |
| 8.00 to 9.00 AM | 10 | 14 | 12 | 79 | 250 | 15 | 23 | 27 | 22 | 4 | 0 | 2 | 0 | 0 | 0 |
| 9.00 to 10.00AM | 24 | 21 | 21 | 82 | 29 | 11 | 9 | 12 | 11 | 0 | 4 | 2 | 4 | 8 | 0 |
| 10.00 to 11.00 AM | 2 | 1 | 0 | 37 | 62 | 18 | 4 | 36 | 28 | 0 | 2 | 0 | 2 | 6 | 9 |
| 11.00 to 12.00 AM | 0 | 1 | 0 | 13 | 70 | 10 | 5 | 22 | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12.00 to 1.00PM | 6 | 8 | 0 | 9 | 50 | 180 | 7 | 19 | 8 | 0 | 0 | 0 | 0 | 0 | 6 |
| 1.0 to 2.00 PM | 7 | 9 | 2 | 143 | 33 | 90 | 11 | 13 | 15 | 0 | 1 | 2 | 4 | 6 | 0 |
| 2.00 to 3.00 PM | 0 | 0 | 1 | 24 | 80 | 70 | 5 | 27 | 18 | 2 | 0 | 2 | 8 | 1 | 0 |
| 3.00 to 4.00 PM | 0 | 1 | 0 | 8 | 10 | 12 | 12 | 4 | 10 | 2 | 0 | 2 | 0 | 2 | 0 |
| 4.00 to 5.00 PM | 12 | 8 | 4 | 17 | 12 | 4 | 17 | 10 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| 5.00 to 6.00 PM | 10 | 7 | 0 | 23 | 10 | 3 | 2 | 6 | 0 | 0 | 2 | 0 | 2 | 1 | 1 |
| 6.00 to 7.00 PM | 0 | 0 | 1 | 3 | 2 | 8 | 0 | 2 | 20 | 2 | 1 | 0 | 1 | 2 | 0 |
| 7.00 to 8.00 PM | 0 | 1 | 0 | 0 | 0 | 4 | 0 | 2 | 18 | 1 | 0 | 0 | 2 | 5 | 0 |
| Total | 85 | 86 | 47 | 479 | 659 | 455 | 109 | 195 | 175 | 13 | 10 | 14 | 23 | 33 | 16 |
| | 73 | | | 531 | | | 159 | | | 13 | | | 24 | | |