# Engineering properties of fine grained soils of Kathmandu Valley, Nepal

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#### **ABSTRACT**

This paper primarily deals with the distribution, and engineering and geotechnical properties of fine grained soils in the Kathmandu Valley. Not much studies have been done on these soils in the past except at some engineering construction sites such as bridges and heavy buildings. Very little data are available on the engineering and geotechnical properties of soils of the valley (IOE, 1983a, 1983b, 1986a, 1986b, 1986c; Koirala et al., 1993; Sadaula, 1993; Shakya, 1987; Soil Test, 1990a, 1990b). The authors conducted detailed laboratory studies on the soils of the Thapathali and Ratnapark areas in the central part of the Kathmandu Valley and the results are presented and discussed. An attempt is also made to broadly evaluate the soil conditions of the valley based on the available data from previous studies conducted by various agencies.

The soils of the Kathmandu Valley are mainly produced by weathering of rocks within its watershed boundary. They are in most part lacustrine and fluvial in origin and composed of clayey, silty, sandy and gravely sediments. The maximum thickness of the sediment is found in the central part (550 m at Bhrikutimandap) and southern part (>457m at Harishidhi) of the valley.

The engineering properties, basically the index properties such as grain size, natural moisture content, specific gravity, Atterberg limits; and the mechanical properties such as penetration resistance, cohesion, unconfined compressive strength, compressibility as well as angle of shearing resistance of fine grained soils were determined and found to vary considerably both in horizontal and vertical directions. The bearing capacity and settlement values of the soils were also determined.

It is commonly found that most of the buildings in the Kathmandu Valley are founded on isolated or strip types of foundations and the foundation depth is between 1 and 1.5 m. The study of soil properties of the Kathmandu Valley indicates that the heavy loaded structures should be founded on either raft, mat or pile types of foundation.

#### INTRODUCTION

Most engineering structures in the Kathmandu Valley are founded on soil. Due to the lack of appropriate legislation as well as unawareness among common people, soil investigations are not carried out as a routine work for engineering constructions except for a very few important and large structures. Almost all private residential houses are constructed without

soil investigation. Rapid urbanization of the Kathmandu Valley in recent years has led to the construction of thousands of private and public buildings without giving due considerations to the nature and the bearing capacity of the foundation soils and the seismic hazards. Even today no systematic and detailed study of the distribution and engineering and geotechnical properties of the soils of the Kathmandu Valley has been carried out by the concerned agencies

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of the government or the Kathmandu Municipality. Data are rare on the engineering and geotechnical properties of soils of the valley (IOE, 1983a, 1983b, 1986a, 1986b, 1986c; Koirala et al., 1993; Sadaula, 1993; Shakya, 1987; Soil Test, 1990a, 1990b). This paper deals primarily with the distribution, and engineering and geotechnical properties of fine grained soils in the Kathmandu Valley based on the works at two sites in the central part of the valley. An attempt is also made to evaluate the engineering properties of the soils of the valley in general based on the available data from previous studies.

# DISTRIBUTION OF SOILS IN KATHMANDU VALLEY

The Kathmandu Valley is an intermontane basin and lies within the Lesser Himalaya of central Nepal (Fig. 1). The soils of the valley are mainly the product of weathering of rocks within its watershed boundary. They are mainly Quaternary sediments of lacustrine and fluvial origin. The soils are composed of clayey, silty, sandy and gravely sediments and are more or less unconsolidated. These sediments lie unconformably over the basement rocks (Yoshida

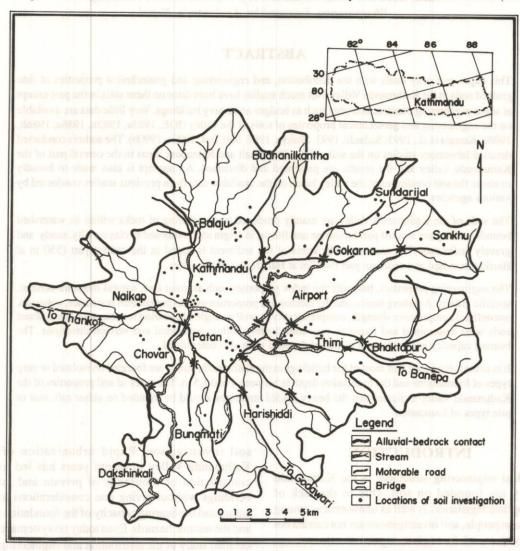


Fig. 1: Locations of soil investigation sites in Kathmandu Valley.

and Igarishi, 1984). Moribayashi and Maruo (1980) conducted gravity survey to understand the basement topography of the Kathmandu basin and concluded that the maximum depth of the basement below the sediments is a little more than 650 m. Based on the bore hole data of Japan International Cooperation Agency (JICA, 1990), Department of Mines and Geology (DMG), and other miscellaneous works, the pattern of subsurface sediment distribution in the Kathmandu Valley (up to 300 m depth) is prepared and shown in two fence diagrams (Fig. 2a, b) and cross-sections (Fig. 3a, b). However, it should be noted that the fence diagrams are based on a limited number of bore hole data. Since there is a significant lateral variations in lithology and thickness of sediments, the diagrams can be used as a general reference and not for site specific works.

The drilling data show that the maximum thickness of the sediments in the valley is more than 457 m at Harishidhi (JICA, 1990, and Fig. 4) where the bore hole did not reach the bedrock. At Bhrikutimandap (exhibition ground) the thickness is about 550 m up to the bed rock (Fig. 4). The thickness of sediment at Bansbari, Gausala and Katunje also touched the bed rock at depths of 79 m, 113 m and 160 m, respectively. But close to these locations bore holes at Gokarna, Koteshwor, Sanothimi and Bhadgaon (Bhaktapur) drilled to depths of 305 m, 305 m, 278 m and 278 m below the ground level respectively did not touch the bed rocks

The fence diagrams and cross-sections show that the coarse granular sediments occupy the north and north-eastern part of the basin while the fine grained deposits lie towards south and south-western part. The number of granular beds also increases towards north and north-eastern part of the basin. The bore holes at Harishidhi, Sunakothi and Lubhu, all lying in the southern part of the valley, show no pure granular zones and consist mainly of thick columns of the sticky black clay.

# ENGINEERING PROPERTIES OF SOILS OF KATHMANDU VALLEY

The present investigation was aimed at the determination of the engineering properties mainly the index properties such as natural moisture content,

grain size, specific gravity, Atterberg limits and mechanical properties such as penetration resistance, cohesion, unconfined compressive strength, compressibility as well as angle of shearing resistance of the fine grained soils of Ratnapark (at Jame Masjid site) and Thapathali (at New Bagmati Bridge site). Index properties of surface soils from various locations of the valley were also determined. As far as possible, previous data on soil investigations at different locations of the Kathmandu Valley were also collected to determine some soil parameters. The results are presented in the Annex.

## **Index properties**

#### Particle size

The grain size analysis of the soils from the Thapathali site (Table 1) shows a clear dominance of fines (i.e. fraction smaller than 75 m). The percentage of sand and gravel is generally very low. The soils of Ratnapark site contain a higher percentage of coarse fraction compared to the Thapathali soils (Table 2).

#### Natural Moisture Content

The natural moisture content (NMC) of the soils of the Thapathali area (Table 1) is generally high (72.96-126.37%) due to the high content of organic matter. The moisture content of the soils of the Ratnapark area (Table 2) varies between 9.1-33.0% (in coarse grained soils) and 9.6-66.3% (in fine grained soils). Various other studies have shown that the moisture content of cohesive soils of parts of the Kathmandu Valley varies between 19.96-94%.

# Specific Gravity

The specific gravity of the subsurface soils of Thapathali (up to a depth of 15 m) ranges from 2.44 to 2.70 and soils of Ratnapark ranges from 2.66 to 2.73 (Table 1 and 2). The specific gravity of the surface soils of Lukundol on the other hand showed a minimum value (2.34) and that of Arubari the maximum (2.67) (Table 3). The lower specific gravity value of soil of the Lukundol area may be due to organic content and that of

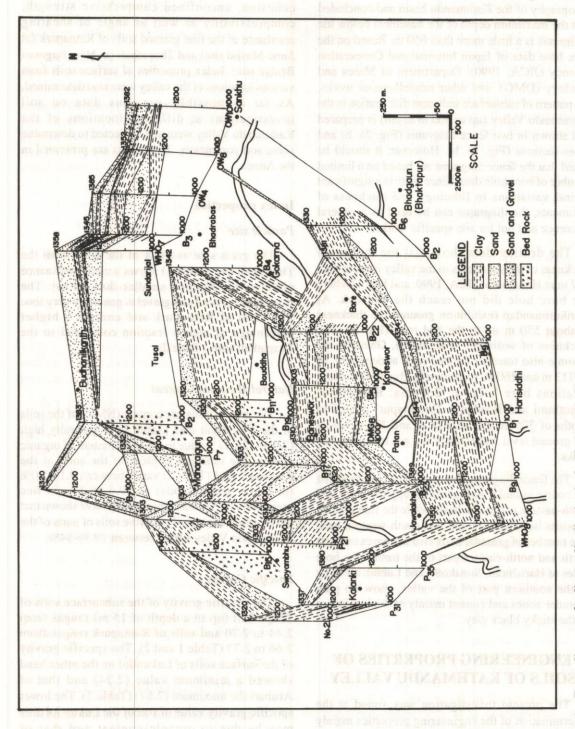


Fig. 2a: Fence diagram of sediment distribution in the Kathmandu Valley.

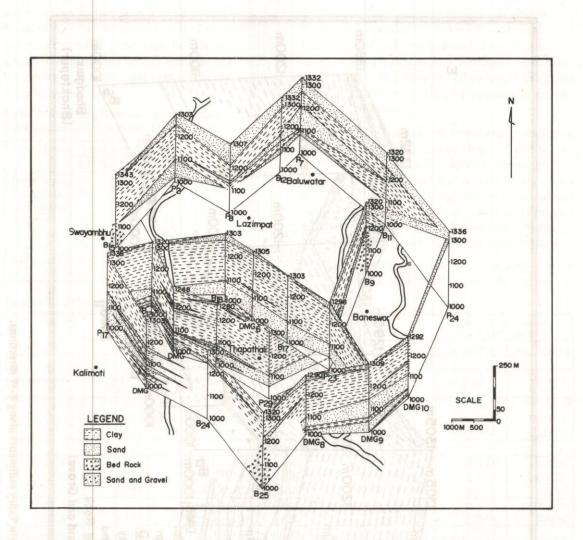


Fig. 2b: Fence diagram of sediment distribution within and adjacent areas of the ring road.

Hatigaudda due to coarse grained nature than that of other parts of the Kathmandu Valley. The values of specific gravity of cohesive subsurface soils of other parts of Kathmandu Valley ranges from 2.51 to 2.77 (Annex).

### Density

The bulk density of cohesive soils of the Kathmandu Valley ranges between 1.09 and 2.77 gm/cm<sup>3</sup> (Annex).

Atterberg limits (consistency limits)

The plastic soils of Thapathali have a high liquid limit (LL) value which ranges between 81.10-108.0% and the plasticity index (PI) ranges between 13.01 to 40.0% (Table 1). The liquid limit of the plastic soils of Ratnapark site on the other hand ranges between 36.0-73.0% and the plasticity index ranges between non-plastic (NP) to 33.0% (Table 2). Soils with higher liquid limit and plasticity index are generally characterized

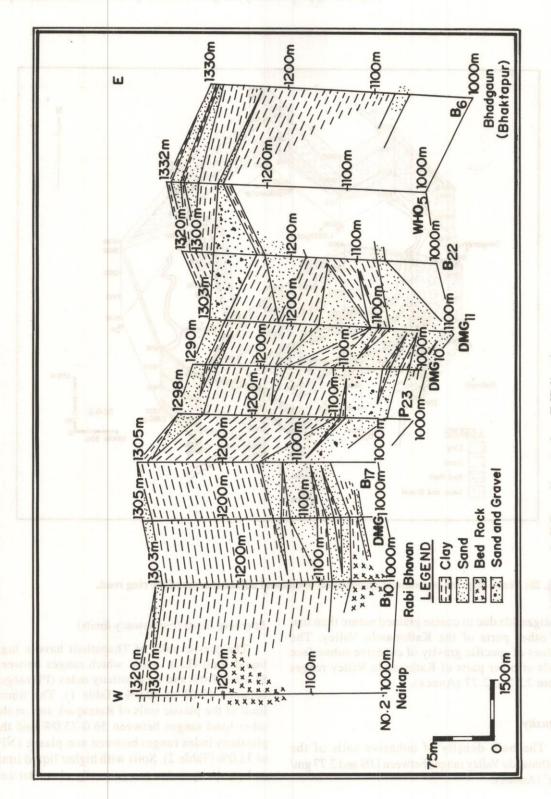


Fig. 3a: Lithological crosssection of Kathmandu Valley sediments along E-W directions.

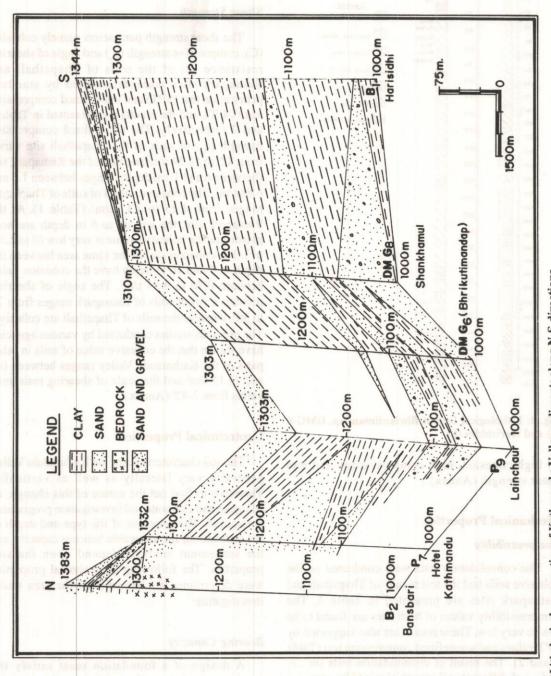


Fig. 3b: Lithological crosssection of Kathmandu Valley sediments along N-S directions.

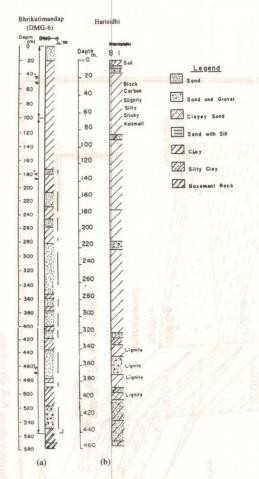


Fig. 4: Lithological logs at Bhrikutimandap, DMG-6 (a) and Harisiddhi (b).

by high cohesion, high compressibility and less shear strength (Annex).

#### **Mechanical Properties**

# Compressibility

The consolidation tests were conducted on the cohesive soils and the test results of Thapathali and Ratnapark sites are presented in Table 4. The compressibility values of both sites are found to be low to very low. These results are also supported by SPT values and unconfined compression test (Table 1 and 2). The result of consolidation tests (m<sub>v</sub>, c<sub>v</sub> and c<sub>c</sub>) of different soil groups obtained by previous studies at various locations and depth in the Kathmandu Valley also shows that the soils are

characterized by low to very low compressibility values (Annex).

#### Shear Strength

The shear strength parameters namely cohesion (C), compressive strength (q,) and angle of shearing resistance (ø) of the soils of Thapathali and Ratnapark sites were determined by standard penetration test (SPT) and unconfined compression test (UCT), and the results are presented in Table 1 and 2 respectively. The unconfined compressive strength (q,) of soils of the Thapathali site varies from 8.5 to 14.34 t/m<sup>2</sup> and that of the Ratnapark site (between 6 and 10 m depth) ranges between 1.5 and 6.68 t/m<sup>2</sup>. The cohesive values of soils of Thapathali ranges from 4.25 to 7.17 t/m<sup>2</sup> (Table 1). At the Ratnapark site, the soil up to 5 m depth are nonplastic and the cohesive value is very low (0 to 2.5 t/ m<sup>2</sup>). The cohesive soil of the same area between the depth of 5 and 10 m depth have the cohesion value between 0.76 to 3.34 t/m<sup>2</sup>. The angle of shearing resistance (ø) of soils of Ratnapark ranges from 28 to 36°, whereas the soils of Thapathali are cohesive. The previous studies conducted by various agencies have shown that the cohesive value of soils in other parts of the Kathmandu Valley ranges between 0.3 and 11.15 t/m<sup>2</sup> and the angle of shearing resistance varies from 2-420 (Annex).

#### **Geotechnical Properties**

The soil characteristics of the Kathmandu Valley generally vary laterally as well as vertically. Therefore to find out the nature of this change, an adequate and elaborate soil investigation programme is required. The selection of the type and depth of the foundation, the allowable bearing capacity and the settlement analysis depend upon the soil properties. The following geotechnical properties were determined for the soils of the area under investigation:

# **Bearing Capacity**

A design of a foundation must satisfy the requirements that no shear failure occurs and the settlement remains within the allowable limits. The bearing capacity of a foundation design depends

5.00

6.75

Plasticity index

PI

PL Plastic limit
NMC Natural moisture content

C Cohesion value LL Liquid limit

Ne Corrected SPT value

Nr Field SPT value Nc Corrected S qu Unconfined compressive strength

4.25

qu t/m2 14.34 13.39 13.50 10.03 8.5 Specific gravity 2.44 2.43 2.54 2.52 2.50 2.50 2.60 2.69 2.46 2.47 2.28 2.48 2.60 2.56 Id % 14.76 26.00 34.52 13.01 40.0 Atterberg Limit
PL % 74.34 76.49 75.00 54.38 0.89 0.101 0.801 81.10 89.50 LL % 6.88 101.95 125.13 126.37 100.69 100.74 NMC % 81.52 88.98 90.00 87.50 72.96 89.92 79.38 73.82 96.06 MH Table 1: Summary of field and laboratory test results of Thapathali soils. Grain size analysis
Sand Fines
% % Fines % 88.66 95.00 94.00 79.00 99.70 99.74 94.00 99.72 95.00 93.00 93.00 81.20 99.50 82.91 0.12 15.20 00.9 0.28 5.00 13.64 14.60 0.30 0.26 7.00 00.9 5.00 0.50 7.00 Gravel % 3.60 3.45 6.40 12.41 8.75 6.25 8.58 17.5 12.45 7.07 13.8 13.2 SPT value 17 7 15 11 25 6 1 15 14.0-14.45 3.0-3.45 6.0-6.35 12.0-12.45 15.0-15.45 4.0-4.45 9.0-9.45 12.0-12.45 8.0-8.45 10.0-10.35 2.0-2.45 3.0-3.45 6.0-6.45 8.0-8.45 Depth Sample No. UDS3 DS<sub>12</sub> UDS, UDS2 UDS1 UDS<sub>1</sub> DS11 DS2 DS9 DS7 DSG DS2 DS3 DS<sub>4</sub> Bore hole No. 7

Ct/m2

UC test

7.17

69.9

Table 2: Summary of field and laboratory test results of Ratnapark soils

m         Nf         Gravel         Samd %         Fines         USCS         %         LL         Pf         Pf         Rp         Cp (m²²         Short         Q m²           30-24.5         8.8         8.8         1.37         8.9         1.3         4.0         8.8         1.0         8.8         1.0         8.8         1.0         8.8         1.0         8.8         1.0         8.8         1.0         8.8         1.0         8.8         1.0         8.8         1.0         8.9         1.0         <	Mr.   Nr.   Gravel   Sand   Figs   USCS   St.   H.   Pt.	Nr    Ne	March   Marc	Bore	_	Depth	SPI	SPT value		Grain Siz	Grain size analysis		NNC		Atterberg Limit	mit	Specific	Direct shear test	ear test		UC test
DS         20-24.5         80         8.5         13.7         13.9         15.0         1	17.5   17.5	Secondary Color	DS 20.245   St. 9.0	No No	No.	ш	ž	Nc	Gravel %	Sand %		nscs	%	LL %	PL %	PI %	gravity	C, t/m <sup>2</sup>		qu, t/	
1978   376.445   310   3145   310   3145   314   3145   314   3144   315   314   3	March   Marc	1985   1985	Dec. of the control		DS	2.0-2.45	8.0	8.56	13.7	82.3	4.0	SW	9.1		,	NP.	2.72	0	35		
UNS	(45) 5.7 (2.2) 1.0 (4.2) 1	Colored Colo	Colored State		DS	3.0-3.45	3.0	3.15	0.0	74.9	25.1	SM	28.9	,	1	25			9		
UDS         6.6545         0.0         1.5         M. 1         51.0         1.0         6.68           BDS         7.3454         1.0         0.0         1.0 <td< td=""><td>6.68         M.         S. 1         S. 1         S. 1         S. 2         S. 6         S. 8           5.6         2.0         1.0         1.5         1.4         8.2         1.2         1.5         1.5         1.5         5.9         1.5         1.5         2.7         5.9         1.5</td><td>  Column   C</td><td>UBS         662-646         Color         <th< td=""><td></td><td>De</td><td>50 5 45</td><td>35</td><td>07.1</td><td>3.0</td><td>0.10</td><td>17.0</td><td>SM</td><td>12.1</td><td></td><td></td><td>Z</td><td>79.7</td><td>1</td><td>87</td><td></td><td></td></th<></td></td<>	6.68         M.         S. 1         S. 1         S. 1         S. 2         S. 6         S. 8           5.6         2.0         1.0         1.5         1.4         8.2         1.2         1.5         1.5         1.5         5.9         1.5         1.5         2.7         5.9         1.5	Column   C	UBS         662-646         Color         Color <th< td=""><td></td><td>De</td><td>50 5 45</td><td>35</td><td>07.1</td><td>3.0</td><td>0.10</td><td>17.0</td><td>SM</td><td>12.1</td><td></td><td></td><td>Z</td><td>79.7</td><td>1</td><td>87</td><td></td><td></td></th<>		De	50 5 45	35	07.1	3.0	0.10	17.0	SM	12.1			Z	79.7	1	87		
UNS	6.63         1         6.6         6.5         99.5         CH         51.1         52.0 </td <td>  Colored Color   Colo</td> <td>  USS   645.656   Color   O. O.</td> <td></td> <td>Inc</td> <td>502 6 45</td> <td>CC</td> <td>S. S. Copper</td> <td>2.5</td> <td>24.0</td> <td>1.3</td> <td>Je V</td> <td>13.1</td> <td>, 000</td> <td>27.0</td> <td>N. C.</td> <td>2.00</td> <td>5.7</td> <td>67</td> <td>100</td> <td>,,,,</td>	Colored Color   Colo	USS   645.656   Color   O.		Inc	502 6 45	CC	S. S. Copper	2.5	24.0	1.3	Je V	13.1	, 000	27.0	N. C.	2.00	5.7	67	100	,,,,
DS	755 7.0 6.23 - 9.66 88.7 CL	15.5   2.0       0.6   98.6   CL   44.1   45.0   28.0   19.0     45   6.0   4.68       14   88.7   ML   40.5   35.0   28.0   19.0     45   6.0   4.68       8.1   87.9   ML   40.5   35.0   21.0     45   6.0   4.68       8.1   87.9   ML   40.5   35.0   21.0     45   6.0   4.68       8.1   87.9   ML   40.5   35.0   21.0     45   2.0   1.48       9.7   89.9   ML   48.8   57.0   35.0   21.0     45   4.0   2.50       0.4   99.5   MH   48.8   57.0   35.0   21.0     45   4.0   2.50       0.4   99.3   MH   30.7   67.0   43.0     45   40   2.52       0.4   99.3   MH   30.7   67.0   43.0     45   5.0   6.24   0.3   88.7   16.0   ML   33.0     NP     45   5.0   6.24   0.3   88.7   16.0   ML   33.0     NP     45   5.0   6.24   0.3   88.7   16.0   ML   33.0     NP     45   5.0   6.24   0.3   88.7   16.0   MH   63.6   39.0   17.0   22.0     45   5.0   2.4   44     6.9   44.1   66.3   39.0   17.0   22.0     45   5.0   2.4   84.1   13.5   87.8   87.8   87.8     45   5.0   2.4   84.1   13.5   87.8   87.8     45   5.0   2.4   84.1   13.5   87.8   87.8     45   6.0   2.4   84.1   88.5   87.8   87.8     45   6.0   2.4   84.1   88.5   87.8   87.8     45   6.0   2.4   84.1   88.5   87.8   87.8     45   6.0   2.4   84.1   88.5   87.8   87.8     45   6.0   2.4   84.1   88.5   87.8   87.8     45   6.0   2.4   84.1   88.5   87.8     45   6.0   2.4   84.1   88.5   87.8     45   6.0   2.4   84.1   88.5   87.8     45   6.0   2.4   84.1   88.5   87.8     45   6.0   2.4   84.1   88.5   87.8     45   6.0   2.4   84.1   88.5   87.8     45   6.0   2.4   84.1   88.5   87.8     45   6.0   2.4   84.1   88.5   87.8     45   6.0   2.4   84.1   88.5   87.8     45   6.0   2.4   84.1   88.5   87.8     47   6.0   2.4   84.1   88.5   87.8     48   6.0   6.5   6.0   6.0   6.0   6.0   6.0     49   6.0   6.0   6.0   6.0   6.0     40   6.0   6.0   6.0   6.0   6.0     41   6.0   6.0   6.0   6.0     42   6.0   6.0   6.0   6.0     43   6.0   6.0   6.0   6.0     44   6.0   6.0   6.0   6.0     45   70   70   80.0     47   8	December   Colored State   C	-	SCI	645-6.90			0.0	0.5	5 66	CH	51.9	53.0	28.0	25.0	267			0.00	3.34
USS   8.0845   7.0   6.23     1.4   887   MI   853     1.4   1.52     1.5   1.5     1.5	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,	1.55   1.0   6.23     1.4   88.7   ML   55.3     1.5   ML   1.5	USA   1767755   776   623   144   887   ML   4853   525	-	DS	70-750	2.0	-	2.	90	986		44.1	45.0	28.0	100	10.7				
UDS         80.84545         6.0         4.68	Mar.	15   15   15   15   15   15   15   15	USS   18845		DS	7 50-7 95	7.0	673		1.4	88.7	N N	553	7.0	0.07	ND ON					
DS   100-1045   Col.   468     81   879   ML   352     879   ML   1352     879   ML   1352     879   ML   1352     879   ML   1352     870	Mar.	155   50   468     81   879   ML   392     NP   1045	DS   10-01-054   Colored   Colored		SOLI	80-845	2:	-				M	40.5	36.0	28.0	8.0			-	1 53	72.0
UDS         110-1145         20         138         3.9         MI         358         3.0         170         5.99           UDS         110-1148         2.0         1.38	1.64   2.0   1.48	1045   2.0   1.48     2.1   2.2   ML   35.8   2.1   2.1   2.1   2.2   ML   35.8   2.2   2.1   2.2   2.	U.S.   110-1145   2.0   4.0	_	DS	90-945	09	468		81	87.0	M	303	2000	0.07	N.O.		2		70.1	0.70
DS   110-11.45   2.0   148     97   899   MT   859   820   22.0	1145   2.0   148	1145   2.0   148     9.7   89.9   ML   48.8   57.0   35.0   21.0     1245   2.0   138     1.1   99.5   MH   48.8   57.0   35.0   22.0     1245   4.0   2.60     0.7   99.5   MH   48.8   57.0   35.0   22.0     1245   4.0   2.52     0.4   99.3   MH   55.4   64.0   42.0   19.0     1245   4.0   2.52     0.4   99.5   MH   55.4   64.0   42.0   19.0     45	DS   110-1145   2.0   148		UDS	10.0-10.45		2011	,	1 .		M	35.8			12	207			6 00	2005
DS         120-1245         2.0         138         -         11         99.5         MH         488         57.0         35.0         22.0           DS         140-1445         4.0         2.60         -         0.7         99.5         MH         36.2         61.0         42.0         1.0           DS         140-1445         4.0         2.60         -         0.7         99.5         MH         36.2         61.0         42.0         1.0           DS         2.0.2.45         8.0         5.66         -         0.4         99.3         MH         36.7         1.0         0.0           DS         3.0.45         7.0         6.24         0.3         88.7         16.0         8.0         -         NP         2.0           DS         5.0.45         7.0         6.7         9.9         MH         35.0         -         NP         2.0           DS         5.0.45         4.0         4.0         8.0         4.1         9.9         4.8         SW         1.0         1.0         0           DS         5.0.45         4.0         4.0         4.0         4.0         4.0         4.0         4.0 <td< td=""><td>  1.545   2.0   1.38   .   1.1   99.5   MH   48.8   57.0   55.0   22.0   .                                  </td><td>  1245   20   138   -                                  </td><td>  DS   120-1245   20   138     111   99.5   MH   48.8   57.0</td><td></td><td>DS</td><td>11.0-11.45</td><td>2.0</td><td>1.48</td><td></td><td>67</td><td>6 68</td><td>M</td><td>369</td><td>53.0</td><td>320</td><td>210</td><td>10.7</td><td>10</td><td></td><td>0</td><td>7.77.3</td></td<>	1.545   2.0   1.38   .   1.1   99.5   MH   48.8   57.0   55.0   22.0   .	1245   20   138   -	DS   120-1245   20   138     111   99.5   MH   48.8   57.0		DS	11.0-11.45	2.0	1.48		67	6 68	M	369	53.0	320	210	10.7	10		0	7.77.3
UDS         130-1345         Colored         Colored         MH         622         610         420         150           DS         140-1445         40         256         -         0.7         99.5         MH         622         610         420         1.20           DS         140-1445         40         256         -         0.4         99.5         MH         557         67.0         420         1.20           DS         2.02-345         10         256         1.3         88.7         16.0         ML         227         -         NP         267         0           DS         4.0-445         6.0         6.24         0.3         88.7         16.0         ML         33.0         -         NP         267         0           DS         4.0-445         6.0         6.24         0.3         88.7         16.0         ML         NP         2.67         0           DS         6.0-454         7.7         6.2         -         -         -         NP         2.67         0           DS         6.0-454         7.7         -         -         NP         -         NP         2.67         0	1345   4.0   2.66     M.H.   6.22   61.0   42.0   150   150   140	1345   4.0   2.60     MH   622   610   42.0   150   154   154   4.0   2.60     0.4   99.5   MH   30.7   67.0   43.0   24.0   154   4.0   2.52   4.0   42.0   150   150   42.0   150	UDS         130-1345         40         2.60		DS	12 0-12 45	2.0	1 38	,	1	5 66	MH	48.8	57.0	350	22.0					
DS 140-1445 40 260 - 0.7 99.5 MH 30.2 67.0 430 240 250 250 250 250 250 250 250 250 250 25	14.45   4.0   2.66     0.7   99.5   MH   30.7   67.0   43.0   24.0	1445   40   2.60   - 0.7   99.5   MH   30.7   67.0   43.0   24.0   24.0   25.2   0.4   99.3   MH   30.7   67.0   42.0   22.0   45.5   6.0   6.24   0.3   83.7   16.0   ML   33.0   - 0.7   NP   45.5   6.0   6.24   0.3   83.7   16.0   ML   33.0   - 0.7   NP   45.5   6.0   6.24   0.3   83.7   16.0   ML   33.0   - 0.7   NP   45.5   61.0   6.72   83.2   33.0   - 0.7   NP   45.5   61.0   6.62   93.4   CL   41.1   - 0.7   NP   45.5   61.0   44.4   - 0.5   69.5   93.1   CL   66.3   93.0   17.0   23.0   17.0	DS		SUL	13 0-13 45	i	200		1		MH	623	610	42.0	100		-			
DSS   150-1545   410   2.52	1545   40   2.52	15.45 4.0 2.52	150   150		DS	140-1445	40	260		0.7	> 00	MIH	30.7	67.0	12.0	240		3			
DS 30-345 80 5.56	Secondary Colored Color   Secondary Color   Se	45         80         5.56         13.6         14.3         12.1         SW         22.7         15.0         17.0<	DS   2,0,2,45		DS O	150.1545	10	250		100	003	MEI	55.4	0.70	45.0	0.47					
DS 50-545 10	1.00   1.00	45 6.0 6.24 0.3 83.7 16.0 ML 33.0 NP 45 6.0 6.24 0.3 83.7 16.0 ML 33.0 NP 45 7.0 6.72 0.8	DS   30.345   10   10.00   13.6   14.3   12.1   SW   22.7   NP   2.67   0   33		200	20.245	0.4	75.7		+:0	27.3	INITI	23.4	0.40	0.74	0.77					
DS	Column   C	45	DS   40445   60   624   624   625   624   625		DS O	30.345	10.0	10.50	13.6	7/13	12.1	AL S	227			OLV	27.67	0	33		
DS   Stocked   To   Color	45  47  672  68	45 70 672 98 1900 MH 233 NP 45 85 80 85 8	DS   S0-545   To   G72   O8   C4   C4   C5   C5   C5   C5   C5   C5		DS	40.445	0.9	624	0.3	82.7	16.0	MG	22.0			N O	2.07		33	-	-
DS         60645         47         0.1         0.2 <td>  1.5</td> <td>  A</td> <td>  DS   60-645   47   124</td> <td></td> <td>De</td> <td>505.45</td> <td>7.0</td> <td>67.0</td> <td>0.0</td> <td>0.7</td> <td>10.01</td> <td>CIU</td> <td>0.00</td> <td></td> <td></td> <td>NE</td> <td>70.7</td> <td>0</td> <td>75</td> <td></td> <td></td>	1.5	A	DS   60-645   47   124		De	505.45	7.0	67.0	0.0	0.7	10.01	CIU	0.00			NE	70.7	0	75		
UDS         645-70         7         -         -         SP-SW         221         -         NP         -         0           DS         70-745         50         -         13         939         48         SW         133         -         NP         2.00         0           DS         80-845         52         -         142         852         39         48         SW         133         -         NP         2.00         0           DS         100-1045         70         546         -         66         934         CL         411         -         NP         2.70         0	7.0	7.0  4.5  5.0  4.1  4.5  5.0  4.2  5.0  4.1  4.2  5.0  4.2  5.0  4.2  5.0  4.2  5.0  4.2  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5	UNS   6457.0   Colored State   Colored State		DS	60.645	47	71.0	0.0			AAC				NB	076	0	33		
DS         7.0-7.45         50         -         1.3         93.9         4.8         SW         13.3         -         NP         2.70           DS         80.845         52         -         4.2         91.6         4.2         SP         12.2         -         NP         2.70           DS         10.0-10.45         5.6         -         4.2         91.6         4.2         SP         12.2         -         NP         2.70           DS         11.0-11.45         6.0         4.44         -         6.6         93.4         CL         66.3         39.0         17.0         NP         2.70           DS         11.0-11.45         6.0         4.44         -         6.9         93.1         CL         66.3         39.0         17.0         NP         2.70           DS         11.0-1.45         6.0         4.44         -         6.9         93.1         CL         66.3         39.0         17.0         NP         2.77           DS         11.0-1.45         6.0         3.78         -         -         2.0         1.0         2.0         2.0         2.0         2.0         2.0         2.0         2.0	45 50	45 50 - 13 93.9 48 SW 133 -	DS   70-745   50   -1   13   93.9   448   5W   153   -1   NP   270   DS   50-845   52   -1   4.2   91.6   4.2   SW   152   -1   NP   2.70   DS   90-845   61   10.9   85.4   3.9   3.80   -1   -1   NP   2.70   DS   10.0-10.45   60   4.44   -1   6.9   9.3.1   CT   66.3   39.0   770   23.0   -2   CT   6.0   3.0   2.0   2.0   CT   6.0   3.0   2.0   2.0   CT   6.0   3.0   2.0   2.0   2.0   CT   2.0   2.		SUL	645-70	ì					WP. GP	221	100		N O	60.7	00	33		
DS         80.845         22         4.2         91.6         4.2         SW         12.2         1.         NP         2.70           DS         90.945         61         -         10.9         85.2         3.9         SW         38.0         -         NP         2.60           DS         110-1145         6.0         4.44         -         6.9         93.1         CL         66.3         39.0         17.0         22.0           DS         110-1145         6.0         4.44         -         6.9         93.1         CL         66.3         39.0         17.0         22.0           DS         110-1145         6.0         3.78         -         1.5         98.5         MH         62.2         67.0         34.0         25.0           DS         10-145         6.0         3.78         -         2.8         97.2         MH         68.3         61.0         46.0         15.0           DS         10-145         9.0         9.7         MH         68.3         61.0         46.0         15.0           DS         4.0.445         9.0         9.4         1.9         88.5         11.0         88.0         15.0<	45 52	45 52 42 91.6 42 SP 122 1 NP 124 10.9 85.2 3.9 SW 38.0 NP 10.45 5.0 444 6.6 93.4 CL 41.1 NP 124.5 5.0 33.5	DS   80.845   52   4.2   91.6   4.2   SW   122   1.0   NP   2.50		DS	70.745	50		13	03.0	18	CW	13.3			MD			37		
DS         90-945         61         -         7.2         3.2         3.2         -         -         NP         2.00           DS         100-1045         7.0         546         -         6.6         93.4         CL         411         -         NP         2.00           DS         11.0-11.45         6.0         4.44         -         6.9         93.1         CL         66.3         370         1.20         -         NP         2.70         -         DS         11.0-11.45         5.0         3.35         -         -         6.9         93.1         CL         66.3         33.0         1.0         3.0         2.00         -         -         NH         62.2         67.0         3.0         1.0         -         -         -         -         NH         62.2         67.0         3.0         2.0         -	1.   1.   1.   1.   1.   1.   1.   1.	1.545   61	DS   90.945   61		DS	80.845	53		42	916	4.0	SD	133			N. O.	07.0				
DS 110-1145 6.0 444 - 6.6 93.4 CL 41.1 - NP 2.72   DS 110-1145 6.0 444 - 6.9 93.1 CL 66.3 39.0 17.0 22.0 - 2.0   DS 11.0-1145 6.0 444 - 6.9 93.1 CL 66.3 39.0 17.0 22.0 - 2.0   DS 12.0-1245 5.0 3.35	10.45   7.0   5.46   -       6.6       93.4     CL       41.1	10.45   7.0   5.46	DS   100-1045   70   546     669   934   CL   41.1     NP   272   CL   100-1045   100-1045   50   444     659   93.1   CL   663   390   170   220   CL   100-1045   50   3.35     1.5   98.5   MH   62.2   67.0   34.0   23.0   CL   150-1545   60   3.78     2.8   97.2   MH   68.3   61.0   46.0   15.0   C.69   CL   150-1545   60   3.78     2.8   97.2   MH   68.3   61.0   46.0   15.0   CL   150-1545   60   3.78     2.8   97.2   MH   68.3   61.0   46.0   15.0   CL		DS	9.0-9.45	19		109	85.2	3.6	MS	38.0			22	2,70				
DS         11.0-11.45         6.0         444         -         6.9         93.1         CL         663         39.0         17.0         22.0         -           UDS         12.0-12.45         5.0         3.35         -         1.5         98.5         MH         53.6         73.0         50.0         23.0         2.69           UDS         13.0-13.45         5.0         3.78         -         2.8         97.2         MH         56.6         73.0         50.0         23.0         2.69           DS         1.0-1.45         2.0         2.14         1.9         85.5         12.6         NM         22.7         -         NP         2.69           DS         1.0-1.45         2.0         2.14         1.9         85.4         1.9         NM         22.7         -         NP         2.69         0.0         93.6         1.0         1.0         1.0         1.0         1.0         1.0         1.0         1.0         1.0         1.0         1.0         1.0         95.9         4.1         SP         3.0         1.0         1.0         1.0         1.0         1.0         1.0         95.9         4.1         1.0         1.0 <t< td=""><td>  1145   6.0   4.44   -     6.9   93.1   CL     663   39.0   17.0   22.0   -                                  </td><td>  1145   6.0   444     6.9   93.1   CL   663   39.0   170   22.0   1245     MH   53.6   73.0   50.0   23.0   15.4     MH   56.2   67.0   34.0   33.0   45.2   67.0   34.0   33.0   45.2   67.0   46.0   15.0   46.0   4</td><td>  DS   110-1145   6.0   444   -     6.9   93.1   CL     663   39.0   17.0   22.0   -                                  </td><td></td><td>DS</td><td>10.0-10.45</td><td>7.0</td><td>5.46</td><td></td><td>9.9</td><td>93.4</td><td></td><td>41.1</td><td></td><td></td><td>d'A</td><td>273</td><td></td><td></td><td></td><td></td></t<>	1145   6.0   4.44   -     6.9   93.1   CL     663   39.0   17.0   22.0   -	1145   6.0   444     6.9   93.1   CL   663   39.0   170   22.0   1245     MH   53.6   73.0   50.0   23.0   15.4     MH   56.2   67.0   34.0   33.0   45.2   67.0   34.0   33.0   45.2   67.0   46.0   15.0   46.0   4	DS   110-1145   6.0   444   -     6.9   93.1   CL     663   39.0   17.0   22.0   -		DS	10.0-10.45	7.0	5.46		9.9	93.4		41.1			d'A	273				
UDS         120-1245         So         335         -         -         -         -         MH         536         730         500         230         -         -         Part of the control of	1245   5.0   3.35   -	1245   5.0   3.35   -	UDS         120-1245         SO         335         -         -         -         -         MH         53.6         73.0         53.0         -		DS	11.0-11.45	0.9	4.44	/ .	6.9	93.1	5	663	39.0	17.0	22.0	1 ,				
DS         13.0-13.45         5.0         3.35         -         1.5         98.5         MH         62.2         67.0         34.0         33.0         2.69           UDS         15.0-15.45         6.0         3.78         -         -         -         MH         56.6         73.0         50.0         23.0         2.69           DS         1.0-1.45         6.0         3.78         -         -         -         MH         68.3         61.0         46.0         15.0         -           DS         2.0-2.45         2.0         2.14         1.9         85.5         12.6         SW         22.7         -         NP         2.75         0           DS         3.0-3.45         10         9.4         1.5         79.4         19.1         SW         22.1         NP         2.75         0           DS         5.0-5.45         10         9.6         2.4         8.1         13.5         SW         22.1         NP         2.7         NP         -           DS         5.0-5.45         10         9.4         1.8         97.4         0.8         SP         15.0         NP         -         NP         - <td< td=""><td>  13.45   5.0   3.35   -   1.5   98.5   MH   62.2   67.0   34.0   33.0   2.69                                      </td><td>  13.45   5.0   3.35   -   1.5   98.5   MH   6.2.2   67.0   34.0   33.0     15.45   6.0   3.78   -     2.8   97.2   MH   68.2   67.0   34.0   33.0     15.45   6.0   3.78   -                                  </td><td>  DS   13.0-13.45   5.0   3.35   -     1.5   98.5   MH   62.2   67.0   34.0   33.0   2.69   DS   DS   15.0-15.45   6.0   3.78   -       -     -       -            </td><td></td><td>NDS</td><td>12.0-12.45</td><td></td><td></td><td>1</td><td></td><td></td><td>MH</td><td>53.6</td><td>73.0</td><td>50.0</td><td>23.0</td><td></td><td></td><td></td><td></td><td></td></td<>	13.45   5.0   3.35   -   1.5   98.5   MH   62.2   67.0   34.0   33.0   2.69	13.45   5.0   3.35   -   1.5   98.5   MH   6.2.2   67.0   34.0   33.0     15.45   6.0   3.78   -     2.8   97.2   MH   68.2   67.0   34.0   33.0     15.45   6.0   3.78   -	DS   13.0-13.45   5.0   3.35   -     1.5   98.5   MH   62.2   67.0   34.0   33.0   2.69   DS   DS   15.0-15.45   6.0   3.78   -       -     -       -		NDS	12.0-12.45			1			MH	53.6	73.0	50.0	23.0					
UDS         150-1545         6.0         3.78         -         -         -         -         -         MH         56.6         73.0         50.0         23.0         2.69           DS         1.0-1.45         2.0-2.45         2.0         2.14         1.9         85.5         12.6         NH         68.3         6.10         46.0         15.0         -         0.0         9.0	15.45 6.0 3.78	15.45 6.0 3.78	UDS         150-1545         6.0         3.78         -         -         -         -         -         MH         56.6         730         530         230         2.69           DS         1.0-145         2.0         2.14         1.9         85.5         12.6         SW         22.7         -         NP         2.75         0         31           DS         2.0-2.45         2.0         2.14         1.9         85.5         12.6         SW         22.7         -         NP         2.75         0         33           DS         3.0-4.45         9.0         9.4         1.5         79.4         19.1         SW         22.1         -         NP         2.75         0         33           DS         4.0-4.45         9.0         9.4         1.8         9.4         1.8         9.4         1.8         1.0         1.0         3.5         1.0         1.0         3.5         1.0         3.5         1.0         3.5         1.0         3.5         1.0         3.5         1.0         3.5         1.0         3.5         1.0         3.5         1.0         3.5         3.5         1.0         3.0         3.0         3.0		DS	13.0-13.45	5.0	3.35	1	1.5	98.5	MH	62.2	0.79	34.0	33.0	2.69				
DS         150-15.45         6.0         3.78         -         2.8         97.2         MH         68.3         61.0         46.0         15.0         -           DS         1.0-1.45         2.0         2.14         1.9         85.5         12.6         SW         22.7         -         NP         2.75         0           DS         3.0-3.45         1.0         9.0         936         0.0         95.9         4.1         SW         22.7         -         NP         2.75         0           DS         4.0-445         9.0         936         0.0         95.9         4.1         SP         33.0         -         NP         2.75         0           DS         4.0-445         9.0         936         0.0         95.9         4.1         SP         33.0         -         NP         2.75         0           DS         5.0-545         10         9.4         1.8         87.4         1.50         -         NP	15.45   6.0   3.78   .   2.8   97.2   MH   68.3   61.0   46.0   15.0   .	15.45   6.0   3.78     2.8   97.2   MH   68.3   61.0   46.0   15.0     45	DS   150-15.45   6.0   3.78     2.8   97.2   MH   683   61.0   46.0   15.0   -     DS   10-1.45   2.0   2.14   1.9   85.5   12.6   SW   22.7     NP   2.75   0   31   DS   3.0-3.45   4.0   4.2   1.5   79.4   19.1   SW   23.5     NP   2.75   0   35   DS   4.0-4.5   9.0   9.36   0.0   95.9   4.1   SP   33.0     NP   2.75   0   35   DS   5.0-5.45   10   9.6   2.4   84.1   13.5   SW   22.1     NP   2.77   1   36   DS   5.0-5.45   10   9.4   18.1   8.5   SW   SW   SW   SW   SW   SW   SW   S	2	NDS				1		,	MH	9.99	73.0	50.0	23.0	2.69				
DS 1.0-1.45	45         2.0         2.14         1.9         85.5         12.6         SW         22.7         -         NP         2.75         0         31           45         4.0         4.2         1.5         79.4         19.1         SW         22.7         -         NP         2.75         0         35           45         4.0         4.2         1.5         79.4         19.1         SW         22.1         -         NP         -         1         36           45         1.0         9.6         2.4         84.1         13.5         SW         22.1         -         NP         -         1         36           45         1.0         9.6         2.4         84.1         13.5         SW         22.1         -         NP         -         1         36           45         1.0         9.4         1.8         97.4         0.8         SP         1.0         NP         -         NP         -         1         36           45         8.0         6.56         13.4         12.3         NML         65.4         400         33.0         13.0         -         -         NP         -	45         2.0         2.14         1.9         85.5         12.6         SW         22.7          NP           45         4.0         4.2         1.5         79.4         19.1         SW         22.2          NP           45         9.0         9.36         0.0         95.9         4.1         SP         33.0          NP           45         10         9.6         2.4         84.1         13.5         SW         22.1          NP           45         10         9.6         2.4         84.1         13.5         SW         22.1          NP           45         10         9.6         2.4         84.1         13.5         SW         22.1          NP           45         8.0         6.56         13.4         78.1         8.5         SW-SM         13.2          NP           10.45         3.0         2.34          0.7         99.3         ML         65.4         40.0         33.0         13.0           11.45         3.0         2.01          1.0         99.0         MH         65.4	DS   1.0-1.45   2.0   2.14   1.9   85.5   12.6   SW   22.7     NP   2.75   0   31		DS	15.0-15.45	0.9	3.78		2.8	97.2	MH	683	61.0	46.0	15.0	•			1	
DS 2.0-2.45 2.0 2.14 1.9 85.3 12.6 SW 22.7 - NP 2.75 0 DS 4.0-4.45 1.0 9.6 2.4 11.5 SP 23.5 - NP 2.67 0 DS 4.0-4.45 10 9.6 2.4 84.1 13.5 SP 33.0 - NP 2.67 0 DS 5.0-5.45 10 9.6 2.4 84.1 13.5 SP 22.1 - NP 2.67 0 DS 5.0-5.45 10 9.4 1.8 97.4 0.8 SP 15.0 - NP 2.73 1 DS 7.0-7.45 2.5 - 0.0 2.0.2 17.8 ML 9.6 - NP 2.73 1 DS 10.0-10.45 3.0 2.34 - 1.3 87.7 ML 65.4 4.00 33.0 13.0 - ND 5.0 DS 13.0-13.45 3.0 2.01 - 1.0 99.0 ML 65.3 43.0 33.0 2.01 - 1.0 99.0 ML 65.3 43.0 33.0 2.07 DS 14.0-14.45 3.0 1.95 - 0.7 99.3 ML 65.2 44.0 32.0 1.0 DS 15.0-15.45 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 1.0 DS 15.0-15.45 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 1.0 DS 15.0-15.45 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 1.0 DS 15.0-15.45 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 1.0 DS 15.0-15.45 3.0 1.89 - 0.8 97.2 MH 56.6 32.0 1.0 1.0 0.0 1.0 0.0 0.0 0.0 0.0 0.0 0	4.5         2.0         2.14         1.9         85.5         12.6         SW         22.7         -         NP         2.75         0         31           45         4.0         4.2         1.5         4.2         1.5         84.1         84.1         87.4         18.1         87.4         18.5         9.6         -         NP         2.67         0         33           45         10         9.6         2.4         84.1         13.5         SW         22.1         -         NP         -         1         30           45         10         9.4         1.8         97.4         0.8         SP         15.0         -         NP         -         NP         -         30         33           45         1.0         2.0         2.0         1.3         87.7         ML         56.4         40.0         33.0         13.0         -         -         NP         -         -         11         36         -         -         NP         -         -         36         -         -         NP         -         -         36         -         -         NP         -         -         36         -	4.5         2.0         2.14         1.9         85.5         12.6         SW         22.7         -         NP           4.5         4.0         9.36         0.0         95.6         0.4         18.1         SP         33.6         -         NP           4.5         10         9.6         2.4         84.1         13.5         SW         22.1         -         NP           4.5         10         9.6         2.4         84.1         13.5         SW         22.1         -         NP           4.5         10         9.6         2.4         13.8         SW         ML         96         -         NP           4.5         10         4.6         1.3         1.2         NP         NP         NP           10.45         3.0         2.34         7.0         ML         56.4         40.0         NP           11.45         3.0         2.96         -         -         NP         NP         NP           11.45         3.0         1.3         3.7         ML         65.4         40.0         3.0         10.0           11.45         3.0         1.25         -         NP	DS   2.0-245   2.0   2.14   1.9   85.5   12.6   SW   22.7     NP   2.75   0   31		DS	1.0-1.45					,										
DS 50-545 4.0 9.0 95.9 4.1 SW 22.1 - NP 2.07 0 DS 50-545 10 9.6 2.4 84.1 SW 22.1 - NP 2.07 0 DS 50-545 10 9.6 2.4 84.1 13.5 SW 22.1 - NP 2.73 1 DS 50-545 10 9.4 1.8 97.4 0.8 SP 15.0 - NP 2.73 1 DS 80-845 8.0 6.56 13.4 78.1 8.5 SW-SM 13.3 - NP 2.73 1 DS 10.0-10.45 3.0 2.34 - 0.7 99.3 ML 65.4 4.0 33.0 13.0 2.67 DS 11.0-11.45 4.0 2.96 - 13.4 98.7 ML 65.3 43.0 33.0 2.01 - 1.0 99.0 MH 63.6 5.0 2.77 DS 11.0-14.45 3.0 1.95 - 0.7 99.3 ML 65.2 4.0 13.0 2.67 DS 11.0-14.45 3.0 1.89 - 0.7 99.3 ML 65.2 4.0 13.0 2.67 DS 11.0-15.45 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 1.0 - 0.7 99.3 ML 65.2 4.0 13.0 2.67 DS 11.0-15.45 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 15.0 - 0.7 99.3 ML 65.2 4.0 13.0 2.67	45 9.0 4.2 1.3 754 12.1 5W 2.3.3 - 1 NP 2.07 0 352 454 15.0 10 9.6 2.4 84.1 13.5 SW 22.1 - NP 2.07 0 352 455 10 9.6 2.4 84.1 13.5 SW 22.1 - NP 2.73 1 36 45 45 10 9.6 2.4 84.1 13.5 SW 22.1 - NP 2.73 1 36 45 45 10 9.6 2.4 13.8 SY ML 9.6 2.1 - NP 2.73 1 36 45 10.45 3.0 2.34 - 0.7 99.3 ML 6.54 46.0 33.0 13.0 - 1 13.0 9.0 MH 6.63 43.0 13.0 2.01 - 0.7 99.0 ML 6.2 44.0 13.0 13.0 2.07	45 90 936 0.0 959 4.13 SW 23.3 - NP A	DS   50-545   4.0   4.2   1.3   1.5   1.		De	20.2.45	0.7	41.7	1.9	20.7	12.0	NS OH	1.77			N.	2.72	0	31		
DS 5.0-545 10 9.6 2.4 84.1 13.5 SW 22.1 PNP - PN	45 10 9.6 24 84.1 13.5 SW 22.0 1 NP - 1 1 3.0 SW 22.0 1 1 3.0 SW SW 22.0 1 1 3.0 SW SW 13.3 1 1 3.0 SW SW SW 13.3 1 1 3.0 SW SW SW 13.3 1 1 3.0 SW SW SW SW 13.3 1 1 3.0 SW SW SW SW 13.3 1 1 3.0 SW	45 10 96 24 18 84.1 13.5 SW 22.1 - NP 45 10 94 1.8 97.4 0.8 SP 15.0 - NP 45 10 94 1.8 97.4 0.8 SP 15.0 - NP 45 1.8 97.4 0.8 SP 15.0 - NP 45 1.8 1.8 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2	DS   50-545   10   96   2.4   84.1   13.5   5W   22.1   10   10   10   10   10   10   10		DS	40.445	00	920	0.0	050	12.1	Sp	22.0			2	70.7	0-	30		
DS   6.0-6.45   10   9.4   1.8   97.4   0.8   SP   15.0   .   .   NP   2.73   1     DS   Ro-8.45   25   .   0.0   20.2   .79.8   ML   9.6   .   .   NP   2.73   1     DS   8.0-8.45   8.0   6.56   13.4   78.1   8.5   SW-SM   13.3   .   .   NP   .     DS   10.0-10.45   3.0   2.34   .   0.7   99.3   ML   66.3   4.00   33.0   13.0   .     DS   11.0-11.45   4.0   2.96   .   1.0   99.0   MH   6.6.3   4.00   3.0   2.77     DS   14.0-14.45   3.0   1.95   .   0.7   99.3   ML   6.2.   54.0   43.0   13.0   2.67     DS   15.0-15.45   3.0   1.89   .   0.8   97.2   MH   56.6   47.0   32.0   15.0   .     DS   15.0-15.45   3.0   1.89   .   0.8   97.2   MH   56.6   47.0   32.0   15.0   .     DS   15.0-15.45   3.0   1.89   .   0.8   97.2   MH   56.6   47.0   32.0   15.0   .     DS   15.0-15.45   3.0   1.89   .   0.8   97.2   MH   56.6   47.0   32.0   15.0   .     DS   15.0-15.45   3.0   1.89   .   0.8   97.2   MH   56.6   47.0   32.0   15.0   .     DS   15.0-15.45   3.0   1.89   .   0.8   97.2   MH   56.6   47.0   32.0   15.0   .     DS   15.0-15.45   3.0   1.89   .   0.8   97.2   MH   56.6   47.0   32.0   15.0   .     DS   15.0-15.45   3.0   1.89   .   0.8   97.2   MH   56.6   47.0   32.0   15.0   .	45 10 94 1.8 974 0.8 SP 150 - 177 NP 2.73 1 36 45 25 - 0.00 20.2 79.8 ML 96 - 180 2.73 1 36 45 80 6.56 13.4 78.1 8.5 SW-SM 133 - 1 NP - 180 2.73 46 8.0 6.56 13.4 78.1 8.5 SW-SM 133 - 1 NP - 180 2.00 46 4.00 4.68 - 12.3 87.7 ML 85.4 40.0 33.0 13.0 - 180 2.00 47 4.0 2.96 - 13 98.7 ML 65.4 46.0 41.0 5.0 - 1 1.0 98.7 ML 65.3 43.0 13.0 2.01 48.5 3.0 2.01 - 1.0 99.3 ML 62.2 54.0 43.0 11.0 2.67 48.5 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 15.0 - 1 1.0 99.3 ML 56.6 47.0 32.0 15.0 - 1 1.0 97.2 MH 56.5 47.0 97.2 MH 56.5 47	45 10 9.4 1.8 97.4 0.8 SP 150 -	DS   60-6.45   10   9.4   1.8   97.4   0.8   SP   150   .   .   NP   2.73   1   36		DS	50-545	10	96	2.4	841	13.5	MS	22.0			N ON			30		
DS         7.0-7.45         25         -         0.0         20.2         79.8         ML         96         -         -         1.2           DS         8.0-8.45         8.0         6.56         13.4         78.1         8.5         SW-SM         133         -         -         NP         -           DS         9.0-9.45         6.0         4.68         -         12.3         87.7         ML         56.4         40.0         33.0         13.0           DS         110-11.45         4.0         2.96         -         1.3         98.7         ML         66.3         4.0         33.0         13.0         -           DS         110-11.45         4.0         2.96         -         1.3         98.7         ML         66.3         4.0         33.0         13.0         -           DS         110-11.45         4.0         2.96         -         1.0         99.0         MH         66.3         43.0         13.0         2.77           DS         140-14.45         3.0         1.95         -         0.7         99.3         ML         65.2         54.0         43.0         11.0           DS         150-15.45<	45         25         -         00         202         778         ML         96         -	45         25         -         0.0         20.2         -79.8         ML         96         -         -         12.4           45         8.0         6.56         13.4         78.1         8.5         SW-SM         13.3         -         -         NP           45         6.0         4.68         -         12.3         87.7         ML         12.2         -         NP           11.45         4.0         2.96         -         1.3         98.7         ML         65.4         4.0         33.0         NP           11.45         4.0         2.96         -         1.3         98.7         ML         65.4         46.0         41.0         5.0           11.45         4.0         2.96         -         1.3         98.7         ML         66.3         43.0         13.0           14.45         3.0         1.20         -         1.0         99.0         MH         66.3         43.0         13.0           14.45         3.0         1.89         -         0.7         99.3         ML         62.2         54.0         43.0         11.0           15.45         3.0         1.89         -	DS   7.0-7.45   25     0.0   20.2   79.8   ML   96       1.2   1.2   1.2   1.2   1.2   1.2   1.2   1.2   1.2   1.2   1.2   1.2   1.2   1.3		DS	6.0-6.45	10	9.4	8	97.4	0.8	SP	150			25	273	-	36		
DS         8.0-8.45         8.0         6.56         13.4         78.1         8.5         SW-SM         13.3         -         -         NP           DS         9.0-945         6.0         4.68         -         12.3         87.7         ML         56.4         40.0         33.0         13.0           DS         110-10-11.45         4.0         2.96         -         1.3         98.7         ML         56.4         40.0         33.0         13.0           DS         110-11.45         4.0         2.96         -         1.3         98.7         ML         66.3         49.0         33.0         13.0           DS         110-11.45         4.0         2.96         -         1.3         98.7         MH         66.3         49.0         5.0           DS         13.0-13.45         3.0         2.01         -         -         -         MH         63.6         43.0         13.0           DS         140-14.45         3.0         1.89         -         0.7         99.3         MH         65.2         54.0         43.0         11.0           DS         15.0-15.45         3.0         1.89         -         0.7	45 8.0 6.56 13.4 78.1 8.5 SW-SM 13.3 NP - NP - 12.2 NP - NP - 12.3 87.7 ML 12.2 NP - NP - NP - 12.3 87.7 ML 12.2 NP - NP - 12.3 87.7 ML 12.2 NP - NP - 13.4 13.0 13.0 13.0 13.0 13.0 13.0 13.0 13.0	45         80         6.56         13.4         78.1         8.5         SW-SM         133         -         -         NP           45         6.0         4.68         -         12.3         87.7         ML         12.2         -         NP           10.45         3.0         2.34         -         0.7         99.3         ML         56.4         40.0         33.0         13.0           11.45         4.0         2.96         -         1.3         98.7         ML         66.3         46.0         41.0         5.0           13.45         3.0         2.01         -         -         0.7         99.3         ML         66.3         46.0         43.0         13.0           14.45         3.0         1.95         -         0.7         99.3         ML         62.2         54.0         43.0         13.0           15.45         3.0         1.89         -         0.8         97.2         MH         63.6         47.0         32.0         15.0	DS   80-8.45   8.0   6.56   13.4   78.1   8.5   8W-SM   133   .   .   NP   .   .   .   NP   .   .   .   NP   .   .   .   .   .   .   .   .   .		DS	7.0-7.45	25		0.0	20.2	.79.8	ML	9.6			-		,	2	-	
DS         9.0-945         6.0         4.68         -         12.3         87.7         ML         12.2         -         NP           DS         11.0-10.45         3.0         2.34         -         0.7         99.3         ML         56.4         40.0         33.0         13.0           DS         11.0-11.45         4.0         2.96         -         1.3         98.7         ML         65.4         46.0         41.0         5.0           DS         11.0-11.45         4.0         2.96         -         1.3         98.7         MH         66.3         43.0         38.0         5.0           DS         13.0-13.45         3.0         1.95         -         1.0         99.0         MH         63.6         43.0         13.0           DS         14.0-14.45         3.0         1.89         -         0.7         99.3         ML         62.2         54.0         43.0         11.0           DS         15.0-15.45         3.0         1.89         -         0.7         99.3         MH         56.6         47.0         32.0         15.0	4.5 6.0 4.68 - 12.3 87.7 ML 12.2 - NP - 12.0 13.0 13.0 13.0 13.0 13.0 13.0 13.0 13	45         6.0         4.68         -         12.3         87.7         ML         12.2         -         NP           10.45         3.0         2.34         -         0.7         99.3         ML         56.4         40.0         33.0         13.0           11.45         4.0         2.96         -         1.3         98.7         ML         65.4         46.0         41.0         5.0           13.45         3.0         2.96         -         1.0         99.0         MH         66.3         46.0         43.0         13.0           14.45         3.0         1.95         -         0.7         99.3         ML         62.5         54.0         43.0         13.0           15.45         3.0         1.89         -         0.8         97.2         MH         56.6         47.0         32.0         15.0           15.45         3.0         1.89         -         0.8         97.2         MH         56.6         47.0         32.0         15.0	DS   9.0-9.45   6.0   4.68   - 12.3   87.7   ML   12.2   -     NP   -     NP   -     NP   -     NP   -     NP   -     NP		DS	8.0-8.45	8.0	6.56	13.4	78.1	8.5	SW-SM	13.3			NP NP					
DS         100-1045         3.0         2.34         -         0.7         99.3         ML         56.4         40.0         33.0         13.0           DS         11.0-11.45         4.0         2.96         -         1.3         98.7         ML         66.3         45.0         41.0         5.0           DS         13.0-13.45         3.0         2.01         -         -         -         MH         66.3         43.0         43.0         13.0           DS         14.0-14.45         3.0         1.95         -         0.7         99.3         ML         62.2         54.0         43.0         13.0           DS         15.0-15.45         3.0         1.89         -         0.8         97.2         MH         56.6         47.0         32.0         15.0	10.45 3.0 2.34 - 0.7 99.3 ML 56.4 40.0 33.0 13.0 - 1.1	10.45 3.0 2.34 - 0.7 99.3 ML 56.4 40.0 33.0 13.0 11.15 4.0 2.96 - 1.3 98.7 ML 66.3 46.0 41.0 5.0 13.0 13.15 3.0 1.95 - 1.0 99.0 MH 66.3 8.0 2.0 1 - 1.0 99.0 MH 63.6 56.0 43.0 11.0 15.4  3.0 1.89 - 0.7 99.3 ML 65.2 54.0 43.0 11.0 15.4  3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15	DS   100-1045   3.0   2.34   - 0.7   99.3   ML   56.4   40.0   33.0   13.0   - 1.0   13.0		DS	9.0-9.45	0.9	4.68		12.3	87.7	ML	12.2			N N			-		
DS * 110-11.45 4.0 2.96 - 1.3 98.7 ML 65.4 46.0 41.0 5.0 COLORS UDS UDS 130-1345 3.0 2.01 - 1.0 99.0 ML 62.3 56.0 43.0 13.0 DS 140-14.45 3.0 1.95 - 0.7 99.3 ML 62.2 54.0 43.0 11.0 DS 15.0-15.45 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 15.0	11.45   4.0   2.96     1.3   98.7   ML   65.4   46.0   41.0   5.0	11.45   4.0   2.96   -   1.3   98.7   ML   65.4   46.0   41.0   5.0     13.45   3.0   2.01   -     1.0   99.0   MH   65.3   43.0   38.0   5.0     14.45   3.0   1.95   -     0.7   99.3   ML   62.2   54.0   43.0   11.0     15.45   3.0   1.89   -     0.8   97.2   MH   56.6   47.0   32.0   11.0     15.47   18.89   -     0.8   97.2   MH   56.6   47.0   32.0   15.0     15.48   15.49   -	DS   110-11.45   4.0   2.96   -   1.3   98.7   ML   65.4   46.0   41.0   5.0   -			10.0-10.45	3.0	2.34		0.7	99.3	ML	56.4	40.0	33.0	13.0					
UDS 130-13.45 3.0 2.01 - 1.0 99.0 MH 66.3 43.0 38.0 5.0 140-14.45 3.0 1.95 - 0.7 99.3 ML 62.2 54.0 43.0 11.0 150-15.45 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 15.0	3.45   3.0   2.01   -   1.0   99.0   MH   66.3   43.0   38.0   5.0   2.77	13.45   3.0   2.01   -   -   -   MH   66.3   43.0   38.0   5.0     44.45   3.0   1.95   -     0.7   99.3   ML   62.2   54.0   43.0   13.0     13.0     15.45   3.0   1.89   -     0.8   97.2   MH   56.6   47.0   32.0   15.0     15.0	DS   UDS   130	3		11.0-11.45	4.0	2.96	-	13	7.86	ML	65.4	46.0	41.0	5.0	100				H
130-1345   3.0   2.01   -   1.0   99.0   MH   63.6   56.0   43.0   13.0   13.0   14.0   14.5   1.89   -     0.7   99.3   ML   62.2   54.0   43.0   11.0   15.0	15.45 3.0 [1.95] - 1.0 99.0 MH 63.6 56.0 43.0 13.0 2.67 [1.64.45] 13.0 [1.95] - 0.7 99.3 ML 62.2 54.0 43.0 11.0 - 15.0 [1.89] - 0.8 97.2 MH 56.6 47.0 32.0 15.0 [1.80] - 1	15.45 3.0 2.01 - 1.0 99.0 MH 63.6 56.0 43.0 13.0 15.0 15.5 3.0 1.95 - 0.7 99.3 ML 62.2 54.0 43.0 11.0 15.45 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0 15	DS   130-1345   3.0   2.01   -   1.0   99.0   MH   63.6   56.0   43.0   13.0   2.67		DS	COS	0		-			MH	663	43.0	38.0	5.0	2.77	20	Sec. Par Par	4	
140-1445   3.0   1.95   -   0.7   99.3   ML   62.2   54.0   43.0   15.0-15.45   3.0   1.89   -   0.8   97.2   MH   56.6   47.0   32.0	1.545   3.0   1.55   -   0.7   99.3   ML   62.2   54.0   43.0   11.0   -	15.45 3.0 1.95 - 0.7 99.3 ML 62.2 54.0 43.0 11.0 15.45 3.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0 15.0 No Corrected SPT value	DS   14.0-14.45   3.0   1.95   -		DS	13.0-13.45	3.0	2.01		1.0	0.66	MH	63.6	26.0	43.0	13.0	2.67				
15.0-15.45 5.0 1.89 - 0.8 97.2 MH 56.6 47.0 32.0	15.45   5.0   1.89   -   0.8   97.2   MH   56.6   47.0   32.0   15.0	15.45   5.0   1.89   -   0.8   97.2   MH   56.6   47.0   32.0   15.0   Ne Corrected SPT value   1.1   1 ionid limit DI	Field SPT value Ne Corrected SPT value LL Liquid limit PL Plastic limit PI Unconfined compressive etrenath		DS	14.0-14.45	3.0	1.95	- HOLE .	0.7	99.3	ML	62.2	54.0	43.0	0.11					
	Ne Corrected SPT value LL. Liquid limit Pl. Plastic limit Pl	Ne Corrected SDT value	Field SPT value Ne Corrected SPT value LL Liquid limit PL Plastic limit PI Unconfined compressive strength		DS	15.0-15.45	3.0	1.89		0.8	2.16	MH	9.96	4/.0	32.0	15.0	,				

upon various factors such as type of soil, size and depth of foundation, amount of settlement that the structure can stand, groundwater condition, etc. The shear strength parameters obtained from field and laboratory tests were used to calculate the bearing capacity of the soils.

Table 3: Atterberg limit and specific gravity of soils of Kathmandu Valley at different locations.

Location	Atterl	erg L	imit	Specific
20.0	LL %	PL %	PI %	Gravity
Sanothimi	32	24	8	2.66
Hatigauda	30	17	13	2.51
(Bansbari)	3	61		8.61
Arubari	47	16	31	2.67
Chabahil	45	18	27	2.51
Chovar	70	37	33	2.58
Lukundol	59	16	43	2.34
Gangabu	9	8.1		2.66

The allowable bearing capacity calculation for a strip type foundation of 1 m width and an isolated foundation of 2x2 m size founded at 1 m and 2 m depth at the Thapathali and Ratnapark sites were calculated using Bowles (Bowles, 1988) and Terzaghi's (Bowles, 1988, p195) equations and are presented in Table 5.

The bearing capacity of foundation soils for an isolated foundation of square shape of 2x2 m size and founded at 2 m depth below the ground level at different locations of the Kathmandu Valley (other than Thapathali and Ratnapark) were calculated using data from previous studies and are presented in Table 6. It is found that the bearing capacity ranges from 6.6 t/m² (Kalimati) to 20 t/m² (Jawalakhel).

A relationship between the allowable bearing capacity and the SPT value for the cohesive soils of

Table 4: Consolidation test results of Thapathali and Ratnapark soils.

Bore hole	Sample		s range kg/cm 0181-0.7244	12		ss range kg/cm 0.7244-1.4489	n <sup>2</sup>		nge kg/cm <sup>2</sup> 0-2.8977
No.	No.	C <sub>v.</sub> cm <sup>2</sup> /sed	m <sub>v</sub> cm <sup>2</sup> /kg	Cc	C <sub>v</sub> cm <sup>2</sup> /sec	m <sub>v</sub> cm <sup>2</sup> /kg	Cc	C <sub>v</sub> cm <sup>2</sup> /sec	m <sub>v</sub> cm <sup>2</sup> /kg
				7	Chapathali				TOWN STREET
A <sub>1</sub>	UDS <sub>1</sub>	0.0483	0.0912	her keeps	0.0877	0.0374		0.1216	0.0289
	UDS <sub>2</sub>	0.0576	0.0787		0.0546	0.0346	-	0.0607	0.0333
Taribi	UDS <sub>1</sub>	0.1488	0.7037	119-91	0.1504	0.7217	-	0.1206	1.4439
A <sub>2</sub>	UDS <sub>2</sub>	0.0373	0.0197	Was 17 6 ()	0.0600	0.0190	HOTOHI (	0.0739	0.0142
-	UDS <sub>3</sub>	0.0544	0.1123	-	0.0661	0.0443	-	0.0614	0.0289
					Ratnapark				
	UDS <sub>1</sub>	0.355	0.910	0.398	0.279	0.032	0.133	4.445	0.020
1	UDS <sub>3</sub>	0.1988	0.083	0.398	0.303	0.026	0.166	0.417	0.022
	UDS <sub>4</sub>	0.280	0.764	0.461	0.325	0.033	0.195	0.198	0.198
2	UDS <sub>1</sub>	0.179	0.086	0.422	0.165	0.028	0.133	0.127	0.0105
	UDS <sub>2</sub>	0.199	0.0076	0.033	0.249	0.076	0.033	0.349	0.004
3	UDS <sub>1</sub>	0.164	0.0155	0.066	0.239	0.023	0.099	0.295	0.0118

 $m_v = Modulus$  of volume change,  $C_v = Coefficient$  of volume change,  $C_c = Coefficient$  of compressibility

Table 5: Allowable bearing capacity of different types of foundations at Thapathali and Ratnapark sites.

Fo	undatio	n	Min.	Unit	Cohesive	Shearing	Allowable	Allowable bea	ring capacity,	Design
Type	Size,	Depth,	SPT	wt.,	value,	angle,	settlement,	t/	m <sup>2</sup>	value
	m	m	value	t/m <sup>2</sup>	t/m <sup>2</sup>	degree	mm	Field Method	Lab Method	
						Thapatha	di			
Strip	1x1 1x1	1 2	7 8	*0.8	4.25 4.25	-	25 25	11.65 13.30	4.20 4.30	4.20 4.30
Isolated	2x2 2x2	1 2	9	*0.8 *0.8	4.25 4.25	:	25 25	8.67 9.89	5.30 5.52	5.30 5.52
						Ratnapar	·k			
Strip	1x1 1x1	1 2	6	1.6	á E	31 30	25 25	9.98 9.98	9.15 11.83	9.15 9.98
Isolated	2x2 2x2	1 2	6 5	1.6 1.6		30 30	25 25	5.78 6.60	9.128 13.03	5.78 6.60

\* submerged unit weight

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Table 6: Bearing capacity for foundation soils of different locations of the Kathmandu Valley for an isolated foundation of 2 m x 2 m sides founded at 2 m below the ground level.

Location	Minimum SPT	Unit weight	Cohesive value	Allowable settlement	Allowable bear	ing capacity, t/m <sup>2</sup>	Design
MAN SHEET AVEC	value	t/m <sup>2</sup>	t/m <sup>2</sup>	mm	Field Method	Lab method	value
Sundhara	9	1.60	5.00	25	19.8	17.2	17.2
Tripureswor	6	1.57	4.00	25	13.2	14.7	13.2
Kirtipur	8	1.28	4.50	25	17.6	16.2	16.2
Chovar	4	1.31	3.00	25	8.8	11.1	8.8
Kupondol	7	1.60	4.00	25	15.4	14.7	14.7
Pulchok	9	1.47	3.80	25	19.8	13.9	13.9
Jawalakhel	11	1.97	5.60	25	24.2	20.0	20.0
Hatiban	5	1.60	3.49	25	10.9	13.0	10.9
Thamel	6	1.60	4.40	25	13.2	16.1	13.2
Bansbari	9	1.60	4.60	25	19.8	16.8	16.8
Sundarijal	5	1.41	2.80	25	10.9	10.5	10.5
Kamaladi	7	1.60	4.00	25	15.4	14.7	14.7
Hatisar	8	1.60	4.00	25	17.5	14.7	14.7
Kamalpokhari	5	1.60	3.00	25	10.9	11.1	10.9
Gyaneshwor	9	1.60	5.00	25	19.8	18.2	18.2
Singhadurbar	12	1.25	5.30	25	26.4	19.8	19.8
Baneshwor	8	1.60	4.00	25	17.5	14.7	14.7
Sanothimi	9	1.60	4.50	25	19.8	16.2	14.2
Suryabinayak	4	1.60	4.00	25	8.8	10.9	10.9
Kalimati	3	1.60	3.00	25	6.6	4.0	4.0
Tahachal	6	1.60	3.80	25	13.2	13.9	13.2

Kathmandu Valley has been prepared (Fig. 5). It is found that the bearing capacity of cohesive soils of Kathmandu Valley generally increases with increase in the N value.

# Settlement

The settlement of foundation soil of Thapathali up to a depth of 4 m below the foundation level

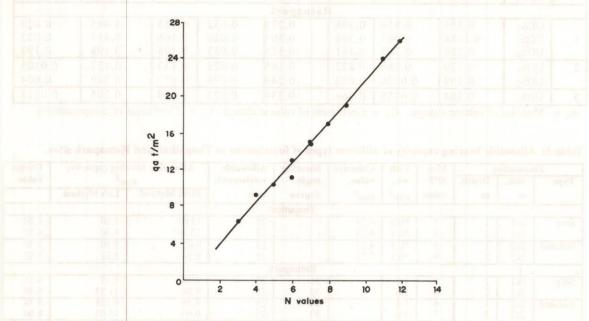


Fig. 5: Relationship between SPT value (N) Vs. bearing capacity (qa) of cohesive soils of Kathmandu Valley.

(according to the standard practice, the settlement of the foundation soil is calculated up to a depth twice the foundation width below the foundation level) calculated for an isolated foundation of sides 2 m taking the calculated minimum allowable bearing capacity of 5.3 t/m<sup>2</sup> and also assuming the foundation soil being homogeneous. The settlement was calculated using Bowels equation (Bowels, 1988). The expected settlement was 33.00 mm (but according general practice the maximum allowable vertical settlement is limited to 25 mm for normally loaded structure assuming the foundation soil is homogeneous). Thus the recalculation of an expected settlement were carried out for a net load of 3 t/m<sup>2</sup> (selected arbitrarily on trial basis). The expected settlement obtained was 19.09 mm for a long term settlement (Table 7).

Allowable loading intensity for Thapathali soils

The calculation of the net loading intensity corresponding to the allowable settlement of 25 mm for the Thapathali soil was calculated as under:

$$q_a = q \times (design settlement)/(actual settlement)$$

$$q_a = 25/19.04 \times 3.0 = 3.94 \text{ t/m}^2$$

Hence, with the addition of unloading intensity caused due to foundation excavation, the allowable loading intensity of the foundation soil is calculated

$$q_n = q_a + rh$$
  
= 3.94 + 0.8  
= 4.74 t/m<sup>2</sup>

Depth	Depth	S Dalley	(Alexa)	HILLS THE	100	SEDVI			Stress	Sett	lemen	t analysis
below ground	below founda-	m =	n=	W ubo	Z		sz t/m <sup>2</sup>	-	due to self	mv,	dh,	settlement s (mm)
surface (z), m	tion, m	b/z	a/z	corner	centre	corner	centre	mean	wt, t/m <sup>2</sup>	cm <sup>2</sup> /kg	mm	s = mv. $\Delta p.H$
0.0	0.0	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0	0.0000	0.00	0.00
0.5	0.0	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.4	0.0000	0.00	0.00
1.0	0.0	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.8	0.0000	0.00	0.00
1.5	0.5	1.4	1.4	0.2102	0.8408	0.6306	2.5224	2.6562	1.2	0.0298	500	3.96
2.0	1.0	1.0	1.0	0.1752	0.7008	0.5256	2.1024	2.3124	1.6	0.0298	500	3.45
	1.5	0.8	0.8	0.1461	0.5844	0.4383	1.7532	1.9278	2.0	0.0298	500	2.88
2.5	2.0	0.7	0.7	0.1277	0.5108	0.3831	1.5324	1.6428	2.4	0.0298	500	2.45
3.5	2.5	0.6	0.6	0.1069	0.4276	0.4827	1.2828	1.4076	2.8	0.0298	500	2.10
4.0	3.0	0.5	0.5	0.0840	0.3360	0.2520	1.0080	1.1454	3.2	0.0298	500	1.71
4.5	3.5	0.4	0.4	0.0602	0.2408	0.1806	0.7224	0.8652	3.6	0.0298	500	1.39
5.0	4.0	0.4	0.4	0.0602	0.2408	0.1806	0.7224	0.7224	4.0	0.0298	500	1.10

The foundation soil of Thapathali site, therefore, may be considered weak. The foundation should rest on compact material placed over the soil to achieve high density or the foundation soil should be compacted to avoid local shear failure in the foundation soil.

The soil profile at Ratnapark has sandy zone up to a depth of 5 m. As this depth lies within the foundation depth (range for normally loaded structures), the settlement analyses were not carried

# FOUNDATION TYPES USED IN KATHMANDU VALLEY

The available bore hole data shows that the main geological units for the foundations in the Kathmandu Valley are the inhomogeneously distributed fluvio-lacustrine sediments. There are only a few areas where foundations can rest on basement rocks.

Except a few heavily loaded buildings owned by the government, semi-government and private parties, all other structures of the Kathmandu Valley have the foundation depth range of 1.0 to 1.5 m and are designed and constructed without considering the soil behavior and loading intensity. It is also observed that most of the normally loaded structures of the Kathmandu Valley are constructed over the isolated and strip type of foundations. Such types of foundations are normally adequate only for lightly loaded structures and on good soil condition. However a few buildings like Karmachari Sanchaya

Kosh (Tridevi Marg), Hotel Sakura International (Lal Durbar), Bagmati Watershed Project (Babarmahal), St. Xavier College (Maitighar), Casino Nepal (Kalimati) and Nepal Electricity Authority (New Buildings at Ratnapark) rest on mat foundations.

The available bore hole data and soil profiles show that the soils of northern and north-eastern part of the valley have better bearing capacity as compared to the central, southern and southwestern part. Broadly speaking it may be concluded that in central, southern and south western part of the valley a heavily loaded structure should preferably rest on a mat foundation.

# CONCLUSIONS AND RECOMMENDATIONS

The soils of Kathmandu Valley are represented by the Quaternary fluvio-lacustrine sediments. They are composed of clayey, silty, sandy and gravely sediments. The maximum thickness of sediments is found in central and southern part of the valley. The southern, south-western and central parts of the valley are dominantly underlain by clays. The sediments show an extreme variation in the material type and soil properties.

In general the soils are weak, i.e. their bearing capacity is low and appropriate foundation techniques should be applied for heavily loaded structures. The bearing capacity of soils of the Kathmandu Valley can be tentatively estimated by the following relationship:

 $q_a = 0.6 \times N$ 

where,  $q_a$  = estimated allowable bearing capacity of soil at explored site in  $t/m^2$ , and

N = SPT value

It is recommended that the government should make appropriate legislation to enforce detail site investigations before any engineering structural designs are approved (especially for the heavy structures).

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Annex: Representative engineering properties of the Kathmandu Valley soils.

	Soil	Depth	Sp. gr.	NMC	Direct shear test	ear test	Con	Consolidation test	test	UC test	Dens	Density (gm/cc)	(cc)	Atte	Atterberg limits	mits
Location	Group	E		%	C, kg/cm <sup>2</sup>	kg/cm <sup>2</sup>	m <sub>2</sub> , cm <sup>2</sup> /kg	Cv, cm <sup>2</sup> /sec	Cc.	qu, 2	Iw	PL	Z	TI%	PL%	PI%
	ОН/СН	0.0-5.00	2.54	81.40	0.5	2.80		0.00106		0.29			1.2	62	31	31
		0.0-5.00	2.45	50.77	0.03		0.0315			90.0			8.0	31.68	16.79	16
	C	5.0-10.0	2.52	50.00	0.03	9	0.0315	0.00125	0.20	90.0			14.0	38.70	19.3	19.4
		10.0-20.0	2.50	48.50	0.115	19	0.081	0.119	0.232	0.23			8.0	39.2	18.62	20.58
		>20.00	2.65	60.50	0.265	4	,	•	•	0.53			8.0	46.10	23.2	23.8
Sundhara	CL-ML	10.0-20.0	2.60	42.66	0.060	6.5	0.0395	0.00413	0.120	40.12			4.0	30.8	20.7	6.10
		0.00-5.00	2.65	48.55	0.18	17	'	0.00019	0.414	0.36			0.6	30.33	-	NP
		5.00-10.0		49.30	0.16	8.9	1	1	0.215	0.32			0.9	32.75	24 51	8 24
	ML	10.0-20.0		43.92	0.1095	17.3	0.0919	0.00041	0.141	0.219			8.0	35.34	27.68	8.00
		>20.00	2.53	44.32	0.265	9.5	1	0.00517	0.13	0.53			0.9	27.65	23.27	4.38
		0.00-5.00	2.65	16.62	0.31	-				0.62		T	8.0	58.0	41.0	17
	MH	5.0-10.0	2.65		0.175	17	1	0.00019	0.414	0.35			12.0	0.09	39	21
		>20.00	2.45	48.59	0.295	'	0.0395	,	1	0.59			7.0	89	47.14	20.86
	CL	5.0-10.	.2.54	32.61	0.41	27	0.0338			0.82	1.09	-	1.0	44.0	23.0	21.0
Tripureswor	ML	0.0-5.00	2.58	33.72	0.266	22			1	0.532	2.03	1.57	0.9	34.40	22.9	11.50
		10.0-20.0	2.66	29.87	0.1655	3.5	-	1	1	0.331	2.08	1.61	3.0	25.4	23.67	1.73
Teku	ML	10.0-20.0	1	-	0.785			-		1.57	•	-	0.9	40.0	29.0	11.0
Kuleswor	ОН	10.0-20.0	2.52	-	0.306	-	-			0.612	1	1	3.0	59.0	20.0	29.0
Balkhu	MH	5.0-10.0	1	35.41	0.3975	1		-	1	0.795			4.0	56.2	31.0	24.2
	CL-ML	0.0-5.00	2.50	28.63	0.405	-				0.804	2.11	1.64	8.0	26.8	19.86	6.14
	C	0.0-5.00	2.59	19.96	0.700	1		1		1.40	2.04	1.26	10.0	33.9	20.54	13.86
Kirtipur	ML	0.0-5.00	2.54	48.39	2.212	21.2	0.032	0.012	*	0.424	1.76	1.20	8.0	48.0	30.34	17.66
		5.0-10.0	2.46	68.78	0.2185	1	1	1		0.437	1.71	1.49	5.0	40.20	22.32	17.88
	MH	0.0-5.00	2.55	57.73	0.300	2.50		1	·	0.600	1.68	1.04	8.0	58.50	40.13	17.97
		5.0-10.0	2.55	16.00	0.61	•		•		1.22	1.73	1.03	7.0	51.7	30.29	29.47
	ML	0.02-5.00	2.63	36.70	0.292	23	0.0597	0.00046	1	0.584	1.71	1.31	4.0	50.1	30.84	19.26
		20.00		59.90	1	1		1	•	•	1.59	0.945	15	43.20	38.4	4.78
Chovar		10.0-20.0	2.60	94.20	0.605	38		1	,	1.210	1.60	0.85	26	83.0	28.58	54.42
	MH	20.0	•	71.30	•	'	•	1			1.59	0.92	14	63.0	45.96	17.04
			0,0	000											200	mE jest
	7	0.0-2.0	2.62	8.09	0.515	'	1.03	,	0.44	1.03	1.61	1	10.0	29.5	20.4	9.1
Kupondole	ML	0.0-5.00	2.63	1 1	0.35	1			0.40	0.70	1.68	1	5.0	42.3	24.8	17.5
		10.0-20.0	2.65	74.25	0.47	1	0.84		99.0	0.94	1	1	4.0	39.8	24.4	15.4

The second second	Soil	Depth	Sp. gr.	NMC	Direct shear test	ear test	Con	Consolidation test	test	UC test	Dens	Density (gm/cc)	(cc)	Atte	Atterberg limits	nits
Location	Group	ш		0,	C, kg/cm <sup>2</sup>	kg/cm <sup>2</sup>	my, cm <sup>2</sup> /kg	Cv, cm <sup>2</sup> /sec	Cc. cm <sup>2</sup> /sec	qu, 2 kg/cm <sup>2</sup>	Tw	Ld	Nc	TT%	PL %	%Id
		0.0-5.00	2.60	28.9	$\rightarrow$	-			-	0.52	1.98	1.43	10.0	30.7	24.0	6.7
		5.0-10.0		31.25	0.05	10	0.0031	0.0008	r	01.0	1.91	1.48	5.0	22.8	25.27	7.53
	CL-ML	10.0-20.0	2.63	38.0	1	1	1	,	-	1		1	5.0	23.81	16.33	7.48
		>20.0			1	-	1	,		1	1.92	1.46	•	28.4	21.91	6.49
Standing.		0.0-5.00	L	34.18	0.31	-	0.0008	E.	-	0.62	1.97	1.49	0.6	30.72	21.91	8.81
Pulchok	CL	10.0-20.0		35.73		1	1	1	-	1	1.82	1.34	0.9	25.35	15.74	9.26
		>20.0		92.68	0.25	5	0.074	0.0008	1	0.5	1.68	86.0	4.0	24.90	15.63	11.31
		0.0-5.0	2.50	34.63	0.49	36	,	1	,	86.0	1.97	1.51	10.0	27.0	22.0	5.0
	ML	5.0-10.0		35.22	0.265	10	0.074	0.0024	1	0.53	1.92	1.57	7.0	30.0	23.0	7.0
Section of the last of the las	-	10.0-20.0		44.40	-	-	•			1	1.75	1.34	0.9	42.0	30.0	12.0
	MH	10.0-20.0	2.60	34.70	1	7	-	,		1	-	-	3.0	53.65	38.45	15.20
Jawalakhel	CT	5.0-10.0	2.60	14.80	-		1	-				-	15.0	40.0	24.0	16.0
The second second section	ML	0.0-2.0		16.60	0.56	•	1	-	1	0.12	2.77	1.97	11.0	29.0	27.0	2.0
Hatiban	CL	0.0-5.0		43.75	0.349	,	1			869.0		-	4.0	45.0	26.0	19.0
Selection of the Select	ML	0.0-5.1		74.67		-	1	-		869'0	,	1	0.9	48.0	39.0	14.0
		10.0-20.0	•	74.72	0.351	1		1	1	869.0		-	0.9	48.0	29.0	19.0
Thamel	ML	0.0-5.0		19.07		7	1			0.880	1	1	0.9	40.0	27.0	13.0
Baluwatar	MH	10.0-20.0	2.57	53.30	0.3725	30.2	0.032	0.00013	-	0.745	1.68	1.09	4.0	45.0	36.5	8.4
250 15 month		>20.0		75.40	0.405	18	0.10	0.0012	1	0.81	1.57	86.0	4.0	35.7	25.0	10.5
Bansbari	ML	0.0-5.0		32.87	0.46	24.25	0.468	0.0002	ı	0.92	1.85	1.41	0.6	39.20	27.51	69.9
delice of the same of	MH	5.0-10.0		88.04		1	1	1	-	-	1	1	1	52.0	31.0	21.0
Sundarijal	CT	5.0-10.0	2.61	19.0		1	1	-	1	0.7	1.09	,	2.0	28.0	17.0	11.0
	ML	0.0-5.0		29.03		34	1	1		0.56	1.86	1	5.0	42.6	26.0	0.91
Kamaladi	MH	0.0-5.0	2.51	33.0	0.42	,	1	1	-	08.0	1.67	1	7.0	52.0	30.0	28.0
	TO	0.0-5.0		-			0.175	-	-	0.79	-	-	7.0	38.2	19.5	18.7
Hatishar	СН	0.0-5.0		54.3	0.395	27	0.17	1	1	0.79	1	1	0.01	58.3	31.2	26.1
Superior of the Paris of the Pa	MH	0.0-5.0		-	-	1	1	1	-		-	•	0.9	51.0	32.0	19.0
	CL	0.0-5.0	1	,	0.23	1		1	1	0.46		1	5.0	42.0	0.91	26.0
Kamalpokhari	СН	0.0-5.0		1	0.36	1	t	1	,	0.72	1	1	5.0	62.0	35.0	27.0
	MH	0.0-5.0	-	1	0-25	0.36		•	-	0.51	-		7.0	96.0	41.0	15.0
THE RESERVED FOR THE PARTY OF		10.0-20.0			1	1				1	1	,	14.0	53.0	39.0	14.0
	ML	0.0-5.0	2.65	21.10	0.46	'		-	-	0.32	-1		11.0	45.0	37.0	8.0
Gyaneswor	100	5.0-10.0		- 011111		•		1		0.92	1.		0.9	0.94	34.2	11.8
	MH	0.0-5.0	2.65	50.85	0.606	1	. 0	1	0.13	1.212	1.79	1.25	7.0	63.0	38.0	25.0
		2.0-10.0	4	73.70			10:0		0.43		1.02	1.1.1		17.0	42.0	73.0

Location	Groun	****		100			STATE OF THE PARTY					Delisity (gill/cc)	(33/	Aller	Atterberg limits	mits
	danoio	E		%	C, kg/cm <sup>2</sup>	kg/cm <sup>2</sup>	my, cm <sup>2</sup> /kg	Cv, cm <sup>2</sup> /sec	Cc. cm <sup>2</sup> /sec	qu, 2 kg/cm <sup>2</sup>	Tw	Lq	ž	"TT%	PL%	PI%
		0.0-5.0	2.62	38.35			'		-	1.112	1	•	10.0	31.68	16.79	15.0
	<del>-</del>	5.0-10.0	2.67	54.23	0.061	1	•	•	1	0.123	1	1	1	34.25	9.91	24.34
	no	100000	2.00	60 64								'	1	48.45	17.19	31.20
		0.02-0.0	2.00	45.00	9,0					1 000		'		02.0	32.0	23.0
, T. J. T.	100	0.0-5.0	65.7	31.73	0.48	1		,00000	1000	0.96	1	1	14.0	42.0	26.0	16.0
Singnadurbar	IMIT	10.0-10.0	20.7	45 34	1115	'	- 80000	0.00086	0.30	•	'	'	13.0	6.0	32.0	12.0
		00103	0 40	77 51			20000	1	1				200	0.00	0.00	0.61
Name of the latest of the late	МН	10.0-10.0	2.40	60.87		•			1		1	•	•	0.09	39.0	21.0
	-	>20.0	2 55	55.70					1		'		'	60.00	27.7	0.12
		0.0200	2 63	73.53	0.36					0.73	1 55			0.00	41.14	20.80
The Real Property lies	3	5.0-10.0	2.63	66.11	0.30		1			0.13	-		0.0	32.0	0.47	0.0
Panacuor	MI	0.01-0.0	2 65	67.60	050					0.012			7.0	33.0	24.0	9.0
Dalicswoi	IMIT	5.0-10.0	2 77	84 37	0.30		1			1.02	1.4/	•	0.0	45.0	31.0	14.0
	174 10	0.01-0.0	71.7	04.37	0.91		-		1	1.82	'	'		40.0	0.72	13.0
	CL-ML	0.0-2.0	' 9	' '	1	1	1	'	'	1	1	'	10.0	250	20.0	5.0
	MH	5.0-10.0	5.69	71.05	1	•	1	1	-	1	1.38		36.0	51.0	34.0	17.0
Koteswor	ОН	5.0-40.0	2.47	1	1	1	1	1	•	1		1	4.0	58.0	36.0	22.0
	НО	10.0-20.0	-	50.80	-		0.36	1	'	1	1.38	0.49	17.0	60.2	32.5	27.8
Gothatar	MH	5.0-10.0	2.65	53.36	0.3875	-		-	-	0.775	1.58	1.03	0.61	0.89	45.0	23.0
The state of the s		10.0-20.0	2.63	55.55	0.4925	•			'	0.985		0.80	25.0	64.0	47.0	17.0
Sanothimi	CL	5.0-10.0		46.80	0.335	-	0.34		-	0.67	-			36.0	22.0	14.0
	СН	5.0-10.0	-	48.70	0.5	11	0.5	-		1.0	1.66	1.08	4.0	53.0	29.0	24.0
Hamumante	ML	10.0-20.0		37.40	0.42	10	0.67	1	-	0.84		1.19	2.0	40.0	30.0	100
	MH	00-20	-	68.0	0.32		0.31			0.64			00	60.03	133.0	0.01
		10.0-20.0	,	41.90	0.45	10.5	0.34			0.0	177	1 13	4.0	54.0	30.0	28.0
	CI MI	0.0.50	2 50	24.88	0.40	2.0.2	1000			0.00	1	01.1	0.4	04.0	30.0	0.07
Verrenineval		0.0-2.0	2.57	37.43	0.42	12.24	1	ı	•	0.04	1.80	1.48	0.0	23.74	18.90	5.29
Suryachinayan	M	0.0-5.0	2.62	36.0	0.42	35.5	0.259	0.001		0.83		1.45	4.0	23.5	10.70	13.1
		0.0-5.0	2.50	54.36	0.31	4	1	1	1	0.60		7.1	2	46.21	23.0	23.21
	CIVOL	5.0-10.0		50.0			0000	9000	0 37	20:0			40	30 5	10.0	10.51
		>20.0		53	1	2	1	-	1	,	,	'	2 '	'49.2	21.0	28.0
		0.0-5.0	2.56	84.01	0.42	2.5	1	-	-	0.84	-		2.0	62.0	33.0	27.0
	СН/ОН	5.0-10.0	2.73	1	,	6.7	-	•	0.14	1	'	1	1	72.1	40.2	31.9
Kalimati		10.0-20.0	1		L	1		,	,	1	•	,		68.52	31.31	37.21
		>20.0	1			00	•	1	1	1	1		•	52.1	26.8	26.3
	ML	0.0-5.0	2.65	52.73	0.30	1	0.0073	-	09.0	0.95	1.61		3.0	48.0	30.0	18.0
		5.0-10.0	2.59	50.0	1	1		•	0.36		1.704		0.9	40.0	27.0	13.0
	MH	0.0-5.0	2.62	61.30	0.481	1	0.00054	-	0.32	0.962		1.69	4.0	57.0	34.0	23.0
		5.0-10.0	1	77.04	0.323	1	0.00015	,	620.0	0.646	1.61	1.56	•	0.09	32.0	28.0
	J :	0.0-5.0	10	39.0	0.36	-				0.72	1.63	1	0.9	38.0	16.0	22.0
Tahachal	ML	0.0-2.0	1	35.0	0.41	1	-	1	99.0	0.82			0.9	40.0	28.0	12.0
MH 5.	МН	0-10.0	- 42	.50	-		-	1	-		1		7.0	51.0	32.0	19.0

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