A Prospective Study of Design and Development Issues of Various Shallow/Hybrid Foundation as Flood and Earthquake proof Foundation

Ajai Kumar Rai, Brajesh Mishra

Abstract**: *In spite of severe , frequent occurrence and causing significant loss of life and property every year due to earthquake and flood ,a large proportion of total population lives in earthquake or/and flood prone areas at risk. As a result of ground shaking due to earthquake event the soil below ground water table loses its strength and stiffness and flows like liquid not only in the lateral direction but also eject to the surface ultimately causing the ground surface to deform /stresses on the buildings on top of the liquefied soil. This can be prevented either by ground improvement or designing heavy duty foundation .Every building stands on foundation but not all the buildings stand on same foundation. As the soils consist of different dominant soil layers in different areas, highly variable stratification and depth, the different requirements imposed on the foundation soils by buildings of different sizes/heights have led to a range of different types of foundations and individual design of building foundation is a must for a building based on total load imposed on foundation and soil characteristics of the area. This paper is not only the study of the different types of prospective foundations, review of ground improvement techniques and identification/determination of soil characteristics of critical area in context to earthquake/flood around Ramgarh lake in Gorakhpur but also it is an attempt to search / development of an optimized foundation for earthquake &flood prone areas.***

Index Terms**: *Optimized foundation, flood prone areas, soil layers, ground improvement techniques.***

I. INTRODUCTION

The stability of any building /structure depend to a large extent on the foundation and it should transmit and distribute the load to the soil in such a way that the bearing capacity of the soil, which is the basic parameter of the design of shallow foundations, is not exceeded. The design of foundations is primarily governed by gravity loads imposed by the weight of the building itself (dead load) and the contents and occupants (live load). If soils close to the ground surface are strong and stiff enough, shallow foundations are provided for walls and columns of the building at shallow depths. Evaluation of the safe bearing capacity and immediate as well as long term settlement is the basic requirement of all type of shallow foundation design. The presence of expansive & collapsible soil makes the construction of foundation extremely difficult due to soil characteristics of the expansive/collapsible soil. Bearing capacity & settlement problems are multiplied when excavation is to be made below ground water table. Due to wide variation of construction problems and specific site condition the boundary conditions and average soil properties are assumed for different strata for working out the detailed foundation design and precautions are taken in implementing a given design that no distress is developed to adjoining structures.

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II. LITERATURE REVIEW

The study area Ramgarh Tal/lake is the portion of Gorakhpur city which is located at the foothill of the greatest or highest hill/hill range of India named Himalayan .As it is only approximately hundred km far from the country Nepal ,the all earthquake and flood events in this city originates from the Nepal ‘s frequent earthquake and rapti /rohini river originating from Nepal respectively .The flood situation further becomes complicated/critical due to surplus discharge in these rivers either in case of heavy rainfall in Nepal or disposing the excess water by Nepal particularly at the time of flowing of the rivers at over discharge capacity in the rainy season. The characteristics feature of the study area i.e low lying area of Gorakhpur City, presence of almost closed huge water body ,kusumhi Jungle ,a thick forest of teak wood ,long time use of edges of Ramgarh tal as solid waste disposal ,inadequate drainage system, enclosed by highway embankments and air force area make it most chronic risky area from both point of view i.e flood &earthquake. The soil of the study area ,on ground of the alluvial soil composition sandy soil/ non-plastic soils,river/lake sediments depositions environment ,rising/lowering of water table,humidity or temperature variation and saturation depth as well as saturated time period , may be considered susceptible to the liquefaction and having complex foundation condition in context to soil suitability as a foundation.

III. PROSPECTIVE SHALLOW/ HYBRID FOUNDATION

The prospective shallow/hybrid foundations to serve as disaster proof foundations for different types of buildings and different types of soils are summarized in table below.

Table 1-Prospective Foundation Types

Foundation Type	Building Type	Foundation Soils
Foundations with tie beam	Up to Three/Four-store y buildings & Low-rise apartment	Shallow alluvial gravel/ sands, silty sands

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Raft foundations	Multi-storey buildings & Low-rise apartment with basement	Shallow alluvial gravel/ sands, silty sands
Raft Pile Foundation	Multy- storey building	Areas of deep soft soils or liquefiable sands underlain by dense sands
Sleeper/ballast based Foundation	All type of buildings	Highly variable foundation soils including shallow gravels and deep silty or sandy soils
Foundations with ground improvement	All type of buildings	Highly variable foundation soils including shallow gravels and deep silty or sandy soils
Wooden Foundation	Multy storey building	Areas of deep soft soils or liquefiable sands underlain by dense sands

A. Shallow Foundation with Grade Beam:

The seismic design of shallow foundations must satisfy the factor of safety of 2or more against bearing capacity failure and adaptability/accommodation of permanent ground deformation by foundation system and superstructure. Lightly loaded structures can be supported on shallow foundations connected by grade beam as the isolated foundation performance during earthquake event is not up to mark. The grade beams may be supported by structurally designed floor slab if sufficient depth of non-liquifiable or stiff soils are lying below the bottom of the footing. Grade beams are designed for 1/10of the maximum column load.

B. Raft Foundation:

For taller buildings a raft(mat) foundation is the most common and widely accepted shallow foundation design specially in the case of earthquake loading or areas underlain by liquified soil deposits,which is based on the assumption that load of the the superstructure is transmitted to the ground directly by the raft. Properly designed mat foundation bridges the gap or uneven ground deformations.

C. Raft Pile Foundation:

Raft foundation spreads the building weight over a wide enough area of soil to keep settlements/differential settlements within permissible limit. In case of inadequate bearing capacity the other option pile foundation is provided in which the entire design load is carried by piles and load is transferred to deep strata through the piles. The recent development in the design of foundation i.e. in between shallow and deep foundation known as piled raft foundation/hybrid foundation for high rise buildings proves to be more economical in case of deeper hard strata. In this type of foundation design the load bearing capacity of the the raft is supported by strategically designed piles and thus the load capacity of the raft is increased and chances of differential settlement is reduced. The load coming from the superstructure is partly shared by raft through soil/ground contact and partly by piles through skin friction. Pile rafr foundation undergoes less settlement than raft foundation and more deflection than pile foundation .The parameters affecting the performance/behavior of pile raft foundation are bending moment on raft,differential settlement, average settlement, size of the raft, thickness of the raft , number of the piles ,diameter of the piles ,length of the piles and spacing of the piles etc. The combination of pile of different length having longer pile at the central portion of the raft, medium piles at the corners /edges and shorter piles in between medium and longer piles may be arranged for better efficiency and effectiveness of foundations.

D. Sleeper Ballast Based Foundation:

Many historical structures surviving more than hundred years have the evidence of the use of utilizing multilayer stones, pouring of sand and installing wooden /timber pieces between the ground and bearing wall to reduce seismic impact on buildings /structures. Multilayer stones with flat and smoothed surfaces provide an easier slide of the structure with respect to the foundation whereas pouring sand creates a slider mechanism during the earthquake event. Wooden beams, tie beams, columns and ring ties are used both in foundation and superstructures. Wooden/timbers used in layers which can roll on each other enable the the foundation /ground to move with the rolling movement of the building ultimately resulting the dissipation of earthquake induced energy. On contrary to this the other technique of the use of timber/wooden member bracings both in horizontal and vertical direction, anchoring of the columns at the roof and at the foundation, bracing of corners with wooden member in both horizontal and vertical direction enable the whole foundation and structure as a monolithic structure during earthquake event ..

Use of the timber layers in between foundation and structure is not only the effective measure for earthquake resistance but also provides moisture prevention to the house, air ventilation under the structure, utilization of the space between the ground and floor as storage and creation of gallery effect. Horizontal wooden member installed in different layers provides the better performance against earthquake and used in combination with vertical member perform well in both in case of flood and earthquake. A permanent displacement of 15-20cm without the damage of the structure is possible as the technique rely on friction only and no restoration force is effective like friction pendulum.

E. Foundations with Ground Improvement:

Any type of foundation on improved ground shall be designed considering the stable soil suitable for foundation. The selection of ground improvement techniques are very complex as the various factors of soil considered for the selection of ground improvement techniques are too many ,some of which are as follows:

- **a)** Type of soil &structure
- **b)** Load distribution on soil
- **c)** Permeability, Compressibility & Strength of soil
- **d)** Skill &Equipment availability
- **e)** Environmental Conditions (Erosion, Water Pollution &Waste Disposal)

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f) Cost &Economies

IV. GROUND IMPROVEMENT TECHNIQUES

The various ground improvement techniques selected for comparative study may be summarized as follows:

a) Vibro Compaction
b) Vacuum Consolidation & Pre –loading
c) Heating &Ground Freezing
d) Impact Compaction method
e) Rammed Aggregate Piers
f) Grouting or Injecting Binders
g) Mechanical /Reinforced Stabilization

The application of depth vibrator increases the density of sandy soil by reducing volume of soil/voids whereas vacuum consolidation of saturated soft soils is achieved by using a vacuum pump. Pore water over time is removed by preloading method whereas crystalline/glass product forming is achieved by heating/electric current. Ground freezing and electro kinetic stabilization, which is the conversion of ground water into ice and the application of electro-osmosis makes water flow through fine grained soil respectively. Four ground improvement methods used in large scale civil construction are impact compaction, rammed aggregate piers, grouting or injecting binders and mechanical/ reinforced soil stabilization.

A. Vibro-compaction/Vibroflotation:

Vibro compaction also known as vibroflotation is a ground improvement process for densifying loose sands to create stable foundation soils is the rearrangement of the soil particles into a denser configuration. The combined action of vibration and water saturation through inserting the vibration probe having diameter 12 to16 inches and frequencies ranging30to 50Hz by both vibration and jetting up to required depth of compaction and filling of granular material usually sand after reaching the probe to the required depth enable the formation of radial zone of granular material as the granular material fills the void space created by vibrator.

B. Vacuum Consolidation &Preloading:

In vacuum consolidation the soil -in -situ is covered with an airtight membrane and vacuum is created by dual venture and vacuum pump. This technique is the replacement of the old standard and most popular technique of the past i. e. preloading and the water preloading and large development in thick compressible soil is possible as compared to the preloading by the adoption of this technique. Preloading has been used as standard method of improving soil properties by placing surcharge/additional vertical stress on a compressible soil for dissipation/removing of pore water for many years without any change in its application procedure. This method is suitable for organic silt,silts and clays,soft clays and dredged material where vibration based techniques performance is not satisfactory and have advantages of reducing post construction settlement and secondary compression, improving the bearing capacity with biggest disadvantage of time dependency and delaying of construction .

C. Heating &Ground Freezing:

Heating of soil through electric current in temperature range 300-1000degree Celsius depending upon the soil breaks the soil particles down to form a crystalline or glass product. Adoption of this technique is limited on the impact of heat on the adjacent structures and utilities. This technique is quite effective in immobilization of radioactive or contaminated soil. Conversion of pore water into ice through ground freezing improves the combined strength of the soil and makes the soil impervious. The converted ice acts as a cement or glue and binds together the adjacent soil particles or rock blocks. This technique can be applied for temporary underpinning, support for excavation, slope stabilization, containment of toxic/hazardous waste contamination and preventing ground water into excavation area.

D. Impact Compaction Method:

In rapid impact compaction method the ground is compacted with a digger attached to the arm of a falling weight whereas in grouting method concrete/pump able material under pressure is injected into the ground,to form concrete columns /bulb for compacting the soil between the compacted columns. Dynamic consolidation/compaction is a good method of compacting as the void ratio or initial density is related to the initial primary settlement as well as secondary compression, compaction (densification) of soils offers an element of control over potential settlement. However, this method will not eliminate biodegradable materials and, instead, may provoke or accelerate migration and/or emission of gas .Dynamic consolidation method involves dropping heavy weights (15 – 20 tons) on to the surface of the fill from a height of 10 to 20m following a selected grid pattern. The high energy impacts produce shock waves that propagate to great depths. As a result, the density of the soil/ fill is increased. With the increase in the density of the soil, the overall bearing capacity is improved. The long-term settlement is reduced and hence, the differential settlement is also reduced which is important for the safety of the structures and damages to the foundations/structures may be avoided.

E. Rammed Aggregate Piers/Stone Columns:

The rammed aggregate piers are formed at suitable spacing through pushing gravel into the ground for compacting the soil between the gravel columns by attaching a hydraulic ram in place arm of a falling weight. Vibro replacement stone columns and vibro displacement are used for improving the bearing capacity of the soil and displacing the soil respectively. In cohesive soils due to excess pore water pressure on account of the installation of stone columns the rate of the reduced settlement of the soil is increased as compared to the rate of normal cohesive soil. In vibro replacement stone columns the reinforcement of the soil with compacted granular stone column by any one of the methods wet top feed method or, dry bottom feed method or offshore bottom feed method provides the control in reduced settlement of cohesive soil ultimately include the cohesive soils also for the application of stone columns technique of ground improvement. The ground improved through this technique reduces the risk of liquefaction during seismic activity,

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Permit construction on fills and construction of shallow foundation as the bearing capacity of the soil improves upto the requirement of shallow foundations. The limitation of this technique is that it is not applicable in case of garbage and maximum depth range 20m – 40m depending upon the ground condition in context to permeation, degree of saturation and relative density.

F. Grouting/Injecting of Binders;

The root level change in the physical characteristics of a soft/weak soil at larger scale can be achieved by grouting i. e. the injection of pump able materials into a soil or rock. A homogeneous mass of the soil is produced due to mixing of the fluids/binders injected with high velocity/pressures and complete breakup of the old soil structure. The various injection grouting techniques used for ground improvement / ground modification are permeation, compaction grouting, claquage and jet grouting. As this method is costliest method proper investigation of soil type, porosity and grout ability supplemented with grouting plan development and prediction of performance and comparative study with other ground improvement techniques is must before application.

G. Mechanical/Reinforced Stabilization:

The reinforcement of metallic strip or geo-grid or geo textiles placed in horizontal successive layers of granular soil backfill containing one or more compacted lifts with free draining non-plastic backfill is connected to a pre-cast concrete or prefabricated metal facing panel to create a reinforced soil mass. In case of metallic strip reinforcement the load is transferred to the strip reinforcement from the backfill soil by shear along the the interface whereas incase of the ribbed strips, bar mats or grid reinforcement the load is transferred in the same way but additional strength is achieved through the passive resistance of the transverse reinforcement. Facing panel may be of any shape either rectangular/square or hexagonal/cruciform upto5 square meter in area. This technique is costly and is used for steeper slope more than 60 degrees. specially in the cases of embankments or edges of the slope

H. Wooden Foundation:

Permanent wood wall foundations are designed or constructed to withstand both lateral load of backfill and axial vertical load and are supported on crushed stone. All the plywood/wood components must be pressure treated with water borne preservative to achieve its resistance against moisture decay and insect damages. In addition to it the timber used in the permanent wood foundation must be in framing form , good quality and sheathing manufactured by plywood consisting of soft wood veneers bonded with exterior adhesive. Cutting or drilling after the treatment requires the field/site treatment of the cut surface and drilled holes. Members 20mm or more above finish grade and interior load bearing walls supported directly on the surface of treated floor system are not required to be preservative treated. The bottom of the wood foundation plate should be located on the granular base having connection to positive mechanical /gravity drainage or the gravelly soil where the permanent water table is below the frost line. If the maximum depth of frost penetration overlaps with the bottom of foundation, the bottom of wood foundation will extend below the maximum depth of frost penetration. Granular footing protection to avoid surface erosion and mechanical erosion must be the part of the foundation design/construction in case of difference between the bottom place and ground level is less than 30cm.

V. RESEARCH METHODOLOGY

A mixed research methodology has been adopted and the data required for the identification of the problem/design & development of the optimized foundation has been collected/arranged through the site survey, questionnaire from the habitat of the selected area, laboratory investigation of collected samples and observation of the constructions going on in the area.

A. Collection/Determination of Data:

The selected area for the study was divided into the parts on mixed radial and hexagonal pattern area covering 4.5 km distance from the periphery of Ramgarh Tal and total 25 locations as per detail shown in Figure1were chosen for the survey, questionnaire, observation, sample collection and laboratory test performance.

Figure1-Details of Study Area

B. Classification of Study Area &Parameters:

The details of broad classification of study area along with sample collection points identification details and locational characteristic features are as per details mentioned in table2:

Table 2-Classification of Study Area

S. No.	Broad Classification	Characteristic Features	Locational Identification of Sample Points
1	Rustampur Area	Almost enclosed area with Highway in north , south and East and Rapti river embankment in the west	Gayatri Mandir,Naval School, Rutampur, Bagaha Baba, Shivaji Nagar, Barago, Rampur

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2	DDU Area	Enclosed from two sides with highway embankment& Rmgarh Tal in south and having railway embankments in north	Kurhaghat Mohaddipur, Padleganj, Barfkhana,Daudpur
3	Air Force Area	Area on both sides of Kasaya Road having railway embankment and a distributor y drain of Ramgarh Lake	Army School,Airforce School,Nandanagar , Vinod Van
4	MMTU Area	Area Along Deoria Road most part of north &west are coverd by Ramgarh Tal	Gopalapur,Jharakhandi,Ranidiha,Kusumhi
5	Taramandal Area	Enclosed Area in north and east (partly) and south by highway embaknkments in the south &westl	RailwayColony,Divyanagar,Ambedkar Park,Gayghat,Siktaur

The various parameters of the elevation, depth, particle size analysis, consistency limits, flow, compression & strength soil characteristics of the selected areas were included in the research analysis to achieve the set objective and are summarized in table2

Table 3-Details of Study Parameters/Properties

S. No.	Parameters	Measured /Collected/Observed/Survey Properties
1	Elevation	Flood Elevation, Ground Elevation, Railway Line Elevation, National Highway Elevation
2	Depth	Rocky Surface Thickness, Alluvial Soil, Water table below G .L., Frost Depth
3	Particle Size	Gravel, Sand, Silt, Clay Percentage
4	Consistency Limits	Liquid ,Plastic ,Plasticity Index
5	Compressive Strength Parameters	Optimum moisture content, Max. Dry density, Compression Index, C B R value
6	Shear Srength Parameters	Cohesion, Angle of Internal Friction
7	Flow Properties	Moisture Content, Porosity, Voids Ratio, Permeability

C. Elevation &Depth Parameter:

For the collection/determination of the parameters required for the design/development of earthquake/flood proof foundation, the exploration or investigation plan was divided into four phases, In the first phase of investigation the design data pertaining to the fixing of plinth level and depth of foundation were explored/collected and are tabulated in table4:

Table 4-Elevation &Depth Parameters

S. No.	Parameter/Properties	Average Value	Maximum Value	Range
1	**Elevation Parameter**			
	Flood Elevation	74.20m above MSL	77.5m above MSL	72-77.5m aboveMSL
	Ground Elevation	66m above MSL	68m above MSL	62m-68m
	Railway Line Elevation	72.5m above MSL	72.5m above MSL	----
	National Highway Elevation	71m above MSL	71.5m above MSL	69.5-71.5 m
2	**Depth Parameter**			
	Rocky Surface Thickness	6000m	6000m	-----------
	Alluvial Soil Cover	6.00-7.20m	6.60m	7.20m
	Water table below G .LPM	4.50-7.50m	6.40m	7.50m
	Water Table Below G.LAM	1.50-4.40m	3.20m	4.40m
	Frost Depth	0.60-0.75m	0.71m	0.75m

On the basis of elevation & depth data average, range and maximum value analysis the plinth level and foundation depth range for different locations may be 72m-74m and 1.00m-1.50m respectively for the economic and safety of the shallow foundations.

D. Particle Size Analysis:

In the second phase of the investigation after fixing the plinth level and depth of foundation both sieve and sediment test/analysis for the identification of texture of the existing soil were carried on samples collected at 1m depth of all the selected location points and test results were further utilized for the determination of gravel /sand percentage, clay percentage, silt percentage and finer particle percentage. The value of the determined percentage of gravel/sand, clay, silt and finer particles from the analysis of test results of both sieve and sedimentation analysis for each broadly classified areas are presented in the figure3:

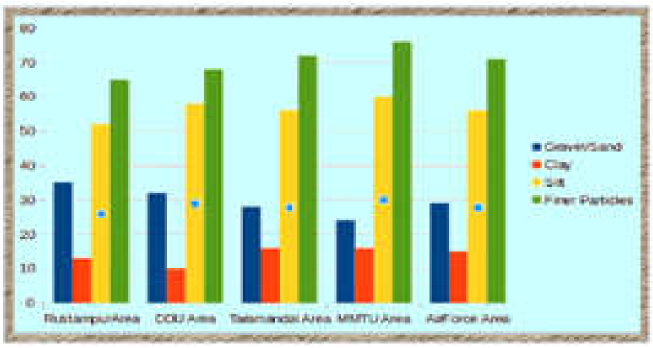

Figure2-Gravel/Sand, Silt, Clay &Finer Percentage

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Evident from the table the study area composed of finer particles less than 0.075 mm dia with an average value of 70 percent and gravel/sand percentage is 30 percent with a marginal variation range. As the finer particles affinity with moisture is more than the coarser particles and less resistant against water flow through soils and lateral forces, the soil may be prima facia characterized as weak soil having liquefied potential.

E. Compressive & Shear Strength Parameters:

In the third phase of the investigation, the various Geo-technical tests for the identification of the strength characteristics of the soil for the confirmation of the prima facia test results of weak soil of the second phase investigation. The direct box shear test, compaction test and CBR test were carried out on all the samples collected at 1m depth and average value of test results for different broad areas of the parameters cohesion, angle of internal friction, optimum moisture content, maximum dry density, compression index and CBR value are summarized in table5:

Table-5- Compressive & Shear Strength Test Results

Parameters	Rustampur Area	DDU Area	Taramandal Area	MMTU Area	Air Force Area
Compressive Strength					
Optimum moisture content	14.60	14.00	15.00	14.80	14.40
Max. Dry density,	01.81	01.76	01.74	01.80	01.78
Compression Index	0.160	0.158	0.162	0.164	0.155
C.B.R.Value	3.80	4.10	3.60	4.40	3.90
Shear Strength					
Cohesion	09.00	10.00	08.00	11.00	12.00
Angle of Internal Friction	05.00	04.50	6.00	08.00	06.50

It is observed from the table that variation in the parameters are almost negligible and the shear strength and compressive strength of the soil of the study area have a low value showing the higher compressibility and lower values of both cohesion and value of angle of internal friction. Thus the test results confirms the prima- facia investigation of the second phase in context to soil strength i. e. weak soil.

F. Consistency Limit & Flow Properties Parameters:

In the last phase of investigation i.e fourth phase of investigation ,the detailed investigation to ascertain the liquefied potential of the soil was taken up keeping in view the importance of this soil characteristic requirement for both flood and earthquake resistances. The tests for moisture content, consistency limits, permeability, porosity and void ratio were carried out in the first fortnight of month June(before the start of the rainy season) and the last fortnight of month July to ascertain the soil conditions both in dry and wet condition. The average value of the test result and determined percentage difference in the average value of the test results are summarized in table6:

Table-6-Effect of Moisture /Saturation in Consistency Limits &Flow Properties

S. No.	Parameter/Properties	Average Value(First Fortnight of June Month)	Average Value(Last Fortnight of July Month)	Difference (%)
1	**Consistency Limit**			
	Liquid Limit	52	46.5	13.04
	Plastic Limit	42	38	10.52
	Plasticity Index	10	8.5	17.64
2	**Flow Properties**			
	Moisture Content	28	34	21.42
	Porosity,	40	37.5	06.67
	Voids Ratio	0.67	0.60	11.67
	Permeability	.0.042	0.045	7.14

As it is evident from the average percentage variation (12.59%) in the consistency limits and flow properties test results that soil have high potential of change in its characteristic in case of moisture availability or saturation. Thus on the basis of analysis of the all phases investigation and test results the soil of the study area may be characterized as weak/unstable soil having the liquefied potential. The chances of adverse effect of earthquake/flood on the civil engineering structures/buildings in this area are more and the survival of the foundation without earthquake/flood resistant measures is not possible. Specific provisions such as ground improvement, use of earthquake/flood resistant materials, and rich mortar are the necessity of the foundation design or construction in this area.

G. Observation of the Construction in Progress:

Two types of foundations of shallow foundations are being presently used i.e. ditch type foundation &construction of piles or columns without raft at spacing of 1.50m-3.00 m or as per plan requirement of size 250x250mm and depth range 1.50m-2.00m are casted by digging holes in the ground. All the columns at the top are connected by grade beam of size 250x250 or 250x300or 250x350mm coinciding with the ground level. The former type of the foundation construction is common in the area/plot located in the built up area on the filled up soil depth varying from 2.40m-3.00m whereas later type is used where the construction is in open area and residential development is in the stage of developing. The second type of foundation has shown its weak performance during flood event due to erosion of soil below the grade beam and also its resistance to earthquake qualifies for the satisfactory level only. This type of foundation requires the maintenance. Underground constructions are rare in the selected area due to low depth of water table below ground level in rainy season and water logging.

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The symptoms of moisture entry or adverse effect of moisture are clearly visible in underground basements.

VI. OPTIMUM FOUNDATION DESIGN AND DEVELOPMENT ISSUES

For the optimum design/construction of earthquake waterproof structures, the following three alternatives of design or construction strategy may be adopted:

(a)The common design and construction issue of the earthquake or flood proof building is to pass the flood surface/subsurface water and earthquake waves respectively from the site of the structure and accumulation of water/moisture and earthquake waves near the site may not happen. This may be achieved or avoided by adopting the following measures individually or with the combination:

(i)Providing sufficient space around the structure in the form of parking, roads, boundary wall around the building,

(ii) Providing space in the form of wooden planks/sleepers in between foundation and superstructure

(iii)Use of stone ballast or coarse sand under and sides of the foundation

(iv) Architectural planning of the ground floor for garage /utilization as storage before and after flood event

(v)In case of large project site or colonial development Providing /designing drains or inverted filters or appropriate drainage system combining open and micro-tunnels.

(b)The most popular and widely adopted/recognized technique for earthquake or/and flood proof constructions is to provide rigidity to the structure or foundation by the use of earthquake /water resistant materials and increasing the resistive strength of the structure by providing grade beam, raft foundation, pile raft-foundation so that the whole foundation and structure perform as a single unit during the flood or earthquake event.

(c)As foundation with ground improvement is the costliest alternative and also the selection of ground improvement technique involves complexity in its performance due to various impact of flood /earthquake in context to soil-structure interaction behavior, hence this type of foundation should be provided only in the cases of large scale projects or colonial development. The use of permanent wood foundation is limited due to the availability of the material, requirement of water borne preservative and poor performance/almost complete damages during strong earthquakes / prolonged flood event.

A. Selection of Foundation:

The optimum choice of the foundation lies in between pile raft foundation and excavated/ditch type foundation. The pile raft foundation consists of arrangement of different depth of piles covering plinth area/plan of the structure and raft thickness 20cm-40cm depending upon the structural load and site conditions as shown in figure3.

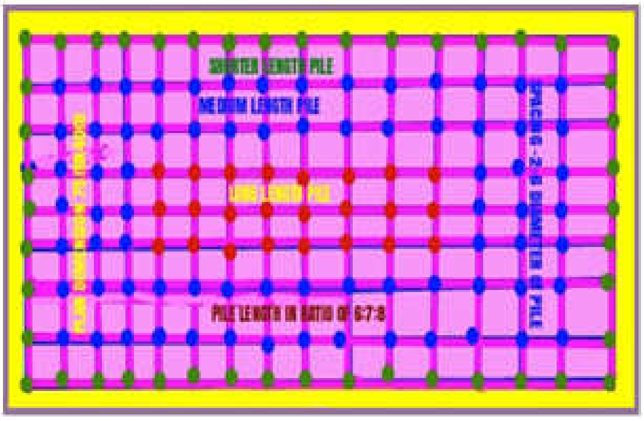

Figure3-Arrangement of different length of piles on a plan 75mx40m

The performance of the different depths of piles during earthquake/frequent flood event/water logging is not very promising. The present study was concentrated on the design /development of ditch foundation with ground improvement of filled up soil. It also includes the use of stone ballast and wooden sleeper to enable the foundation more resistant. First and foremost requirement of all design or development activities is the characterization of the soil of the area for deciding the plinth level ,selection of type of foundation and avoiding the settlement and other problems due to presence of weak/problematic soil before / after construction.

B. Assumptions:

The following assumptions/limitation is applicable to the design /development of the foundation:

(a)The foundation has been constructed on filled up soil and proper drainage connection developed impervious layer and open space in the form of setback/boundary wall construction are provided in the developed ground.

(b) The shallow soil has low bearing capacity , too deep stiff soil strata or rock and difference in maximum flood elevation and ground elevation/rock strata neither permit the safe shallow foundation nor permit the economical deep foundation on the existing ground..

(c)The water table is sufficient below the bottom of the foundation, which should be below the frost depth.

(d)The developed foundation design is restricted to the buildings up to 12m height.

C. Fixation of Plinth Level:

The fixation of the plinth level should be carried out on the basis of maximum flood level, existing railway track and national highway levels. Theoretically it should be maximum flood level but a compromise up to minimum of the above three levels is possibly safe and economic as the chances of maximum flood level occurrence are less frequent usually once in 25 or 30years.However in case of the existence of the railway track or national highway beyond 2Km the local survey questionnaire from the habitat and difference between the existing ground should be the basis for the fixation of plinth level.

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It should not be fixed on the basis of existing local road as the level of the local road and bottom side drainage rise, which is quite common will create accumulation of water around the building and drainage problem with no alternative solution except frequent pumping by collecting the water in a pit.

D. Design/Development of Optimum Foundation:

After collecting the data and assumptions made the ditch type foundation was designed for the selected area considering the soil characteristics with provision of wooden sleeper/stone ballast compacted layer below the foundation was developed /designed as shown in figure4.

Figure4-Designed/Developed Foundation for Earthquake& Flood Prone Areas

In case of ground elevation and maximum elevation difference up to 2m and soil having required bearing capacity this foundation will be an optimized foundation for earthquake and flood prone areas. All the sites where difference of ground elevation and maximum flood elevation is more than 2m the development/improvement of the ground is pre-requisite of the shallow foundation design/development. If the construction is to be carried out at the large area scale i.e. development of the residential colony or project, the dynamic compaction or vitro-flotation techniques should be adopted depending upon the characteristics of existing soil and locally available soil fill material. For small area scale or individual residential quarter cases stone columns or geo /mechanical reinforcement techniques would be the right choice. The developed ground area should be at least 1.5 times the plinth area or plot area whichever is less. The improved ground must contain an impervious stable layer at 1.5m depth below the developed ground level. The plate load test for the determination of the bearing capacity of the improved ground must be carried out before the construction of foundation.

VII. CONCLUSION

The different selected foundations were compared with the developed foundation on the parameters of initial cost, maintenance, benefits, performance against flood & earthquake, strength of foundation, life of foundation on a four point scale of satisfactory, good, very good & excellent as shown in table 7.

Table-7-Comparision of Prospective Foundations & Optimized Foundation

PARAMETER	OPTIMIZED	FWTB	RAFT	RAFT PILE	SBF	FWGI	WF
Initial Cost	1	4	3	2	2	1	3
Maintenance Cost	4	1	2	3	3	3	2
Drainage Benefits	4	2	2	3	3	3	1
Performance Against Flood	4	1	3	3	3	4	2
Performance Against Earthquake	4	2	2	2	4	4	3
Strength of foundation	4	2	3	4	3	4	2
Life of Foundation	4	1	2	3	3	3	2
Total Score=28	25	13	17	20	21	22	15

As evident from the table that developed foundation design is much more safe and resistant against the earthquake & flood as compared to the other possible alternatives of shallow/hybrid foundations and inclusive of the characteristic features of sleeper ballast foundation and foundation with ground improvement except the initial cost which depends on soil characteristics of the soil. and elevation of the existing ground. If the stiff shallow layer of soil exist and the suiting ground level as per requirement maximum flood level the initial cost of the foundation is affordable.

REFERENCES

1. Al-Karni, A.A. and Budhu, M.,(2001) "An Experimental Study of Seismic Bearing Capacity of Shallow Footings", Proc. 4th International Conference on Recent advances in Geotechnical Earthquake Engineering and Soil Dynamics and symposium in Honor of Professor W.D. Liam Finn, CD-ROM, San-Diego, CA, 2001.
2. Baidya, D.K. "Earthquake Resistant Design of Shallow Foundations" Department of Civil Engineering, I.I.T. Kharagpur.
3. Balakumar V., Kalaiarasi V. and Ilamparuthi K. 2005. Experimental and Analytical Study on The Behaviour of Circular Piled Raft on Sand, Proc. 16th Intl Conf. on Soil Mechanics and Geotechn
4. Cooke R.W. 1986. Piled Raft Foundation on Stiff Clays – A Contribution to Design Philosophy, Geotechnique, 36(2),169 -203
5. Caltrans. (2013). Caltrans Seismic Design Criteria, Version 1.7, California Department of Transportation, Sacramento, CA.
6. EUROCODE 8 (EUROPEAN PRE-STANDARD 1994). "Design Provisions for Earthquake Resistance of Structures-Part 5: Foundations, Retaining Structures and Geotechnical Aspects," The Commission of the European Communities.
7. Knappett, J.A. and Madabhushi, S.P.G. (2009). "Seismic Bearing Capacity of piles in liquefiable soils." Soils and Foundations, Japanese Geotechnical Society, 49(4), 525-535.
8. Kumar, J. and Kumar, N.(2003), " Seismic Bearing Capacity of Rough Footings on Slopes using Limit Equilibrium, Geotechnique, 53(3), (2003), 363–369.
9. Kumar, K. (2008). "Basic Geotechnical Earthquake Engineering". New Age International Publishers.

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10. Liu, L., Dobry, R., (1997). "Seismic Response of Shallow Foundation on Liquefiable Sand". J. Geotech. Geoenviron. Engng., ASCE, 123(6), 557-567.
11. Liu, H. (1995)."An Empirical Formula for the Evaluation of Building Settlements due to Earthquake Liquefaction". Proc. 3rdInter. Conf. Rec. Adv. Geotech. EQ Engrg. & Soil DynamicsVol. 1, 289-293.
12. Marcuson, W.F. and Haynes, M.E., (1990), "Stability of Slopes and Embankments During Earthquakes", Proc. ASCE/Pennsylvania Department of Transportation Geotechnical Seminar, Hershey, Pennsylvania.
13. Mendoza, M.J. and Avunit,G. (1988) The Mexico Earthquake of September 19,1985-Behavior of Building Foundations in Mexico City", Earthquake Spectra, 4(4)
14. Poulos H.G. 2001. Piled Raft Foundation: Design and Application, Geotechnique, 51(2),111-113
15. Yamashita.K , Hamada.J, Yamada.T. 2010. Field Measurements On Piled Rafts with Grid-Form Deep Mixing Walls on Soft Ground, Geaotechnical Engineering-SEAGS .42(2) .

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