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Role and Review of Problem Diagnostic Techniques in Strengthening of Foundations: A Case Study of Southern Half of Gorakhpur City in U.P.

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ABSTRACT
Almost all low rise buildings suffer with movement /distress as a result of moisture /water table variation in the soil, characteristic changes in existing soil around and below foundation due to flood/earthquake ultimately leading to differential settlement. The symptoms of foundation failure due to differential settlement in different parts of foundation is always evidenced by development of vertical cracks. However before the failure each foundation/building gives one or more of the indications such as wall rotation, separation around garage walls, cracked bricks/ sheet/ rocks / floors / foundations, displaced moldings, mis-aligned doors and windows. For the strengthening /modification of foundation obtaining information through observation of cracks, failure paten and measurement of the features/components is the unavoidable necessity to identify the failure mechanism, origin of the trouble/problem and role of ground conditions in context to failure of foundation partly or wholly. This paper deals with the novel based study of foundation problem diagnostic techniques, prospective/ constraintitve review of the strengthening techniques supplemented with the case study of almost southern half of Gorakhpur City through survey, observation and questionnaire from the occupants for the foundation problem identification and its strengthening measures.

Keywords- Strengthening techniques, cracks, failure pattern, differential settlement, water table.

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I. INTRODUCTION

For proper selection of strengthening of the foundation, the awareness of the weakness of the foundation is quite necessary. If the uplift threat of the foundation exists, the retrofitting techniques such as adding new foundations, dimension increase of existing foundation, decreasing uplift potential of foundation by supporting/ connecting vertical component latterly. Elimination of the risk of the high pressure of the soil under the foundation can also be achieved by improvement of the soil around/beneath the foundation. In case of single foundation under the risk of uplift it can be connected through deep concrete beam with the adjacent foundation.

After the identification of foundation problems the condition assessment of a building foundation is carried out with the objective to categorize the building foundation in three categories i.e. the foundation where no retrofitting/repair/modification is required due to foundation showing no sign of distress and satisfies the strength criterion as per code provisions, the foundation / building is badly damaged and structural safety of foundation permit the demolition and new construction and the repairable /modification /regaining of strength of foundation is possible. Foundation strengthening techniques are concerned with the third category only. For the achievement of the objective the recorded damages along with cause plays and important role in the selection of foundation strengthening techniques .Foundation evaluation parameters based on characteristics and defects & tests commonly adopted along with the details of properties are summarized as follows in tabular form.

Table 1 Summary of foundation evaluation parameter characteristics / defects and tests

S.No.	Parameter	Characteristics &Defects	Evaluation Tests
1	Dimensional Properties Checking	Slab, Grade beam, Raft &,Pier Levelness, Flatness, Dimensions and Depth/Thickness	Ground probing &penetration radar, Inspection opening and Excavation, Laser, spirit & optical level, Manometer & Concrete cores
2	Di-stressing Symptoms in Foundation	Width, Length, and Type of Crack, Delamination, Detrimental Chemical Reaction, Honey combing, joint deficiency, Spalling, Curling &Warping	Chain dragging, Hammer sounding &echo, Petro graphic examination, Ground probing &penetration radar, Inspection opening and Excavation , Concrete cores, Resistivity, Ultrasonic pulse velocity, Visual
3	Foundation Material Properties	Durability, Compressive Strength, Air Entrainment, Chloride Content, Water/ Cementious Ratio, Hardness, Unit Weight	Chloride ion content testing, Concrete screw driver test, Rebound hammer, Petro graphic examination, Concrete cores
4	Reinforcement Characteristics	Reinforced- Depth of cover, Location, Spacing, Size, and presence of corrosion Prestressed- Tendon assembly consisting of the strand, grease, sheathing, and anchorages and profile.	Half cell potential, Metal detector, Post tension tendon liftoff &screw driver, Reinforcement location, Visual, Chloride ion content testing, Ground penetration radar, Inspection opening and excavation
5	Soil Physical & Engineering Properties	Consolidation, Moisture Content, Plasticity Index, Soil shear strength, Soil strata location,	Geotechnical, Ground probing & penetration radar, Inspection opening and Excavation, Resistivity, Visual

6	Moisture Movement	Rate of moisture vapour emission	Plumbing (Leak detection), Resistivity &vapour Transmission

II. FOUNDATION PROBLEM DIAGNOSTIC TECHNIQUES

The foundation problem diagnostic techniques may be broadly classified as follows:
(a) Traditional techniques
(b) Mechanical equipment/instrument based techniques
(c)Electrical/electronic equipment based techniques
(d)Specific properties based techniques
(e)Other techniques

2.1. Traditional Techniques

The various traditional techniques for the evaluation of foundation condition assessments may be summarized as follows:
(i) Visual/Rapid Observation Technique
(ii) Inspection Opening &Excavation
(iii) Use of Different Types Of Levels
(iv) Hammer Sounding &Chain Dragging

2.1.1-**Visual/Rapid Observation Technique**

Visual Observation is the first, oldest and widely adopted non-destructive evaluation method. The objective of visual observation is the collection of complete detailed information of design , drawings , architectural provisions in the building, geotechnical, construction, repair or retrofitting details and uses/utilization of building in the past and recording of all the items of distress or design deficiency and their locations, supported by sketches /drawings and measurements. It also includes the identification of nondestructive tests to check the strength of masonry, major alterations in the original construction documents, visible structural damage such as concrete cracking or spa1ling, potential non-structural falling hazards, soil condition and the foundation type and severity of damage and make judgments about further course of action.

Visual Observation supplemented by measurements and photographs as a first step provides the basis for further detailed investigation. Though visual observation evaluation is inexpensive, non-invasive and do not require special equipment or specific expertise, however it does not give conclusive investigation and very much depend on the evaluator personal experience of similar type of problems/situations. Rapid (Visual) Investigation consists of collection of detailed information related to the past of the building foundation under investigation in context to design, construction, uses, maintenance and modifications/alterations in the original design/construction if any, visual inspection of site conditions, recording details of distress symptoms and evaluation /estimation of safety of buildings in context to building code provisions or desired/required specific provisions. Visual observation of settlement/differential settlement in case of soil liquefaction, land slide and top surface rupture caused by flood/earthquake play an important role in the diagnostic of foundation condition.

2.1.2- Inspection Opening &Excavation

Inspection opening &excavation technique consists of observations of damages/severe damages, cracks at openings, windows, slab ,exterior and interior separation, expansion joints, squareness of openings, crawl space, drainage, spaces near foundations, excessive moisture symptoms such as Soggy soils, water table in submerged cavities, efflorescence, algae, standing water, and aquatic plants, exterior building line, horizontal and vertical movement of flatwork, grass and shrubs near the foundation, existing pool slope and leaks, previous foundation repair works ,tree and heavy vegetation nearby foundation and lastly but not leastly the topography of the area. Though moderate foundation movement does not show damages, however characteristic indicative damages are those which not only give the indicative information in context to foundation movement direction and severity but also provides the platform/basis for the consult /advice / opinion for remedial measures. The characteristic feature of the cracks at windows /and doorways exterior and interior surface of the building shows that distortion in framing follows the parallelogram pattern during movement and separation of door/window from the finished materials or surface. Crack location, size and pattern determine the possible causes of crack location e.g. considering the fitting of the door within the jamb-an indication of movement in horizontal direction, failure Local drop/rise is observed in case of exterior trim separation from the finish whereas interior separation on walls to ceiling and between structural components and surfaces are accompanied by foundation movement but never indicate the nature of movement. In case of differential foundation settlement expansion joint movement should be examined. Cracks through concrete grade beam and framing are categorized as severe damages as the same is caused due to the heavy movement of

foundations, adverse effect on foundation functioning and may compromise the ability of the structure. Possibility of water entering in crawl space and drainage of water from the crawl space, existing depression, sump pumps, swells, drainage condition whether poor or proper must be thoroughly checked and possibility of modifications for the proper drainage from the vicinity of the foundation must be ensured for the satisfactory performance of the foundations.

2.1.3- Use of Different Types Of Levels

Spirit Level consists of narrow straight body insect made of wood, aluminum or injection fiber glass with spirit filled vials which is made of glass filled with colored ethanol installed in the body through the use of insert for the purpose of easy repairing and body/ insert vial is the cutout for easily view bubble ,which due to shape of the vial tube indicates levelness /plumbness during use. In the case of use for the foundation, the arrangement is made to allow the vial to be viewed from the above. Though longer levels up to length of 8ft or more used in foundation construction/retrofitting works have higher accuracy in case of the surface flatness providing/determining but shorter levels ranging in length from 2-4 feet called torpedo is used in the foundation evaluation work as the same is easily and conveniently handled/transported. Normally a vial level is used in conjunction with measuring tape for slope measurement and provides only approximate results and chances of possible errors are more. The spirit level also known as carpenter level have the advantages of quick interpretation due to analog display, checking of slope direction, foundation elevations.

Recent development in the spirit level in the form of displaying digital numeric in degrees from level/plumb or percent grade or rise or run with the sense direction of gravity with an accelerometer is known as digital level. Digital level provides superior performance in context to accuracy in case of surfaces far from level or plumb in the quantitative deviation terms than the spirit level which is used to determine the difference from plumb and level for small/shorter deviations in non-quantitative form. Digital levels ,which provide difficulty in assessment of slope direction, are more expensive, requires batteries and affected by environmental temperature variations whereas vial levels are fragile, affected by rough handing and drops, breakable and requires periodic checks through rotating the level through 180 degrees.

A Laser Level consists of a laser head producing laser beam rotating in the horizontal plane to produce a leveled laser plane and laser pole either visually graduated rod or a laser sensor enable to emit a signal after the sensor alignment with laser beam. Visual displays and audible outputs indicating on-level, too low , too high is displayed by sensor. Laser leveling system sensor range and accuracy are as long as 1600ft and 1/16 inches in 100ft respectively. This system performs better in open unlimited sites whereas poor/unsatisfactory performance in typical residential /low rise buildings and poor environmental lighting condition.

For the measurement of elevation difference between two points through optical level a graduated level rod(staff) is sighted with level which consists of a telescope rotating in horizontal plane with built-in-cross-hair mounted on a tripod adjusted to allow eye level access for the measurement of elevation difference between two points. Auto self-leveling instruments have replaced old optical level as the internal mechanism maintain the instrument in level position if the instrument is placed in nearly level position.. With the development of digital instruments utilizing a bar-coded rod read by instruments whan a switch is activated have become a widely accepted instrument for the determination/evaluation of elevations within a fraction of seconds.

2.1.4- Hammer Sounding &Chain Dragging

Hammer Sounding & Chain dragging is a relatively inexpensive and non-required specific tools/expertise qualitative technique for the identification of anomalies, void space and discontinuity in concrete slab/foundation. In this technique variation in sound i.e. ringing/mute/hollow from the reverberations produced by rattling the chain of different diameter from 1/2 to 1/4 inches is the basis of identification of anomalies in the continuity of the underlying material or striking the ordinary masonry hammer on the surface and listening the response. The portable and easiness equipment/procedure and survey a large area quickly by chain dragging and hammer sounding for small area are the characteristic feature of this technique whereas exact location depth non-availability and requirement of test results verification by other tests and giving more general indication depending upon the experience of the observer are the limitations.

2.2- Mechanical Equipment/Instrument Based Technique

Metal detectors and ground probe are used to measure the presence and location of steel reinforcement and dimensions of grade beam /visual observation of soil type .Metal detectors are used to obtain information regarding the presence and location of steel reinforcement in concrete foundation, flat work and joints based on magnetic field intensity variations. Ground probe is a general T-shaped plumbing steel rod of 10mm diameter

1.20m-1.50m long having lower end conical shaped upset tips for breaking the skin friction. This is used to measure the depth of grade beam, visual observation of soil type and soil water condition from the catching/returning soil at the tip during pull-out of the plumbing rod.

2.2.1 - Metal Detector

This equipment is portable (hand held) and able to penetrate air/concrete/other interfering faces due to which on the access of one side of the reinforcement audio or/ visual signal are displayed. The limitations of the metal detector are maximum penetration depth limit in concrete (10-15cm) and faulty signal in case of congested reinforcement area/presence of metal fibers/pieces in concrete. For the identification of reinforcement location and size of embedded steel the instrument. R-meter based on changes in electrical inductance in case of presence of underlying ferromagnetic metal within the concrete. The attached display unit provide digital display in the form of cover and diameter of the reinforcing bars .Modern R meter are able to provide three dimensional view of the reinforcement and cover. This equipment have same limitations as the metal detector.

2.2.2- Ground Probing, Penetration Radar and Sonar Ground probing /penetration radar is the only technique based on geophysical principles in case of clustered urban condition for the identification of air voids ,structures , ditches and discrete feature such as pits, hearth, garden features etc inside and outside in a wide variety of soft landscaping to concrete(hard surfaces).It utilizes pulsing electromagnetic waves magnetic strength and delay time of receiving signal in the identification of density, depth and all important extra details desired about the underground structures/foundations.

A recent innovation in the field of ground conditions investigation known as ground penetration sonar is the development of a device having a transducer driven with two frequencies directed towards the ground through a silastic waveguide having a non-linear characteristics producing a narrow beam of acoustic energy. In presence of underground structures (third frequency) reflection of the narrow beam in the form of rapid attenuation in amplitude becomes the basis of sub soils objects or structures location/ identification.

2.3- **Electrical /Electronic Equipment Based Techniques**

Instrument to measure ultrasonic pulse velocity and reinforcement meter is used for the assessment of the existing concrete quality and reinforcement location respectively with greater precision.

2.3.1- **Ultrasonic Pulse Velocity**

This method is based on the principle that stress waves, which depends upon aggregate type & contents, water content and reinforcement in concrete travel faster in compact concrete(more than 3600m/sec) as compared to the concrete having void space/poor concrete. The speed of the ultrasonic pulse stress wave is measured by using a pair of electro acoustical transducers one as emitter whereas other as receiver placed at the two opposite faces of the concrete with a coupling agent allowing transmission of the pulse through the interface. In other words the distance between transducers or path of the pulse of the stress compression wave is fixed. For longer path lower frequency transducer ranging 15-25 kHz and for shorter path higher frequency transducer ranging from 80-100kHz is used as more variation in ultrasonic pulse velocity is desirable in case of longer path. This test is used to assess the quality of concrete element of foundation by detecting relative uniformity of concrete and damages i.e. voids. declamations, cracking and honey comb applicable to length /width of concrete element right from 50mm to 15m. As the access to both opposite faces/ends of the foundation is required, this test can be performed on elevated concrete element or at least two opposite faces of concrete are made accessible by excavating the sides of the foundation. Besides simple, compact, portable and easy usability equipment this test gives only qualitative results and requires proper care and interpretation of the results obtained as this may be adversely affected by coupling used on signal strength of transducers through transferring of ultrasonic pulse, degree of saturation of concrete and presence / amount of steel reinforcement.

2.3.2- Reinforcement Locator/Meter

Modern reinforcement meter are able to provide three dimensional layout of the reinforcement and concrete cover including digital displayed showing cover and diameter of steel reinforcing bar by measurement of changes in electrical inductance due to presence of ferromagnetic metal. This equipment which is portable, battery powered, one side of access required and non -requirement of placing over the concrete surface utilizes the electromagnetic signal to locate the steel reinforcement with a great precision. Depth of penetration more than 15mm, areas with concentrated reinforcement and presence of metal fibers in concrete mix produces inaccurate signal and even prevent the signal.

2.4- Specific Properties Based Techniques

The properties based techniques include the testing of foundation material i.e. concrete / steel and

soil through a dozen number of tests for the identification of existing concrete/soil physical & engineering characteristics.

2.4.1- Chloride Ion Content Testing

As all chlorides present in concrete are not responsible for corrosion only water or acid soluble chloride techniques are used for the determination of chloride ion content in concrete. However, all chloride in aggregate and organic chloride present can be measured by fusing a concrete sample with calcium oxide. Water soluble techniques are the most effective and widely adopted which measures the present chloride content in concrete made available by grinding and extraction procedure. The value obtained is treated as representative value of total chloride ion content in concrete for corrosion as the acid soluble chloride content has almost nil effect on corrosion. For the evaluation of chloride ion penetration movement form concrete surface to the reinforced steel the samples at the different levels covering the complete concrete thickness of the foundation element is required. However the samples obtained from the vicinity of the steel reinforcement provide sufficient indicative figure of chloride ion content in context to adverse effect of it on reinforcement.

The maximum value of chloride ion content permissible in concrete ranges as 0.20 – 0.40 percent of cement mass in case of reinforced concrete and .10-0.20 percent of cement mass for pre-stressed concrete. There is no chance of corrosion in low chloride content and high PH value greater than11 whereas higher pH value and chloride content in the range 0.40-0.60percent by the weight of cement gives the indication of corrosion prone. Even in case of low pH value the chloride content greater than 0.60 percent by weight is not admissible as it indicates highly /extremely corrosion prone.

2.4.2- Concrete Core Testing

Existing foundation elements may be evaluated by testing concrete core samples of typically 10-15 cm in diameter and 15-20cm length obtained by drilling and extracting at strategically selected locations of the concrete elements of existing foundations. The selected locations should cover the suspected concrete strength showing symptoms of damage/deterioration /changes warranting concrete strength in context to defective design /construction. The various tests in on the collected and transported concrete core samples in the lab includes test for compression strength, hardness, moisture content, permeability and aggregate soundness/durability. The patching of the concrete core holes for the restoration of original concrete aesthetic appearance is necessary. After the adjustment applicable factors as per code provisions the test results give reliable value if sufficient or large number of samples are collected. The problems of concrete core sampling may be soil excavation, pavement cutting and patching , requirement of tunneling and source of water for drilling/coring ,presence of reinforcement in the core sample location and finally the ability /accessibility of core drilling equipment. For the evaluation of condition of concrete, chemical and lighting techniques through microscope on obtained core sample known as petro graphic examination is carried out. This test is performed in all conditions i.e. sample as received, on prepared lapped or polished thin cross-section, fractured sample and powder mount prepared by scratching away very small amount of paste. Almost all type of microscopes including stereo microscopes, glass microscopes and polarized/transmitted light microscopes used in petro graphic information may provide the following reliable information about the existing condition of the concrete foundation:

(a) Quality and soundness of concrete
(b) Cement Content and percent of entrained air
(c) Degree of concrete consolidation
(d) Type of aggregate and its acid solubility
(e) Presence of deposits or contaminants/micro cracking
(f) Sulphate attack (internal) in hardened concrete due to curing, composition and exposure
(g) Alkaline (Cement)silica (Aggregate) reaction responsible not only for delayed ettrangite formation in the form of visible dislocation and cracks in concrete but also with risk increase due to freeze/thaw attack and corrosion of reinforcement

2.4.3- Partial Destructive Testing on Concrete

Partial Destructive Tests consisting of penetration resistance ,pull out and pull off tests are surface zone tests requiring at least exposed concrete surface and cause too small damage not liable for any loss in structural performance. These tests require lesser number of parameters as compared to surface hardness and ultrasonic pulse velocity tests as the assessment of the strength of concrete is carried out through correlation charts. These tests are reliable ,fast, less disruptive and damaging as compared to core testing.

The basic principle of penetration resistance test is to evaluate the resistance of existing concrete through firing of specially designed bolt in the form of standardized explosive cartridge following standard test procedure and correlating the concrete strength with depth of penetration and pattern of failure.

Pullout testing method meant for the measurement of concrete strength through correlation of force required to pull a bolt or embedded material either at the time of casting or

epoxy grouted through hole in concrete is the most reliable and popular method known by different names such as north American pull out method, Lok test, Internal Fracture Test, ESCOT,CAPO etc all over the world.

The pull off test based on the measurement of in-situ tensile/compression strength of concrete not only provide the resistive strength of the concrete but also the bond strength which plays an important role in case of addition of new concreting with old concrete. This test is carried out by applying a traction force on a metallic disc previously bonded with epoxy resin on the surface of the concrete until the breakage of the concrete away. The tensile force required after calibration becomes the basis of the assessment of the compressive strength as well as bonding strength of the existing old concrete and newly epoxy resin bonded metallic disc. For the assessment of bonding strength the metallic disc must be partially below the surface.

2.4.4- Resistivity As Evaluation Parameter For Existing Foundation

For the investigation of ground composition the geophysical testing method of the measurement of resistivity is a common and most popular technique in the form of resistivity survey through inducing an electric current into the soil through positive and negative probes in a linear array at the specified spacing range 1.50-3.00m as electrodes to measure the voltage drop depending upon soil resistance. The depth of resistivity measurement is directly proportional to the length of probe line. Resistivity survey may provide the information in context to underground location of pre- existing water body, foundations, plumbing leaks, caverns ,void space, drainage condition, landfills, tree root zone , accumulation of ground water and above all it provides clear idea of existing soil strata variations. Though resistivity survey have the advantages of finding quick results available on site, portability of field equipment and non destructive in case of grade outside /along foundations but this is not the substitute of geotechnical testing as the interpretation by geotechnical and geophysical specialist is the basic requirement for obtaining a reliable value/result. Resistivity measurement supplemented by standard geotechnical testing through soil boring test parallel to the probe line will produce reliable results. Resistivity survey in concrete foundation requires drilling of holes about 12mm diameter and then patching of holes after the testing.

2.5- Other Techniques

If leak is suspected around/beneath a foundation plumbing also referred as leak detection test which consists of supply and sprinkler line pressure test, hydrostatic, isolation, flow, sanitary system video tests,storm water drain line and visual evaluation of air conditioning conduit line is carried out. This test is performed only in the case of lifting of foundations to ensure the effect of lifting foundation on sewer pipe line safety i.e breakage.
Vapor emission rate, which can be measured/assessed from the concrete slab/floor surface indicates the quality and moisture presence in concrete of the existing slab /floor.

2.5.1- Plumbing (Leak Detection) Techniques

For performing hydraulic testing on sanitary system a rubber bladder is inserted at the sanitary system exit and water is run until the system is full and if there is no change in level of water surface level recorded at the approximately half an hour after the water filling of the system ,then system is said to be leak proof. If there is change in the water surface level recorded and no mal-functioning with rubber bladder, then system is detected as leaking system. For the identification of location/isolation of leakage the whole system is divided into blocks through using two or more rubber bladders and the same procedure is adopted for each section. Once the leakage location is identified a camera may be inserted for the documentation of the leakage and loss of volume of water is assessed through supplying the known discharge through the system and collecting the same at the exit/possible locations .The loss of water through leakage is equal to the difference between the initial volume and collected volume of water during the period of supply hours.

2.5.2- Vapour Emission Rate Based Technique

The vapour emission rate of a slab on ground for preliminary or quality assessment is carried out by putting anhydrous calcium chloride on exposed surface area of the slab covered with a plastic cover for 2.5 -3 days. The darken or gel color of calcium chloride shows low emission rate while liquefaction of it shows higher emission rate. In case of higher emission rate weight gain in anhydrous calcium chloride is determined by placing the weighted calcium chloride and plastic container and weighing the same after three days of placing in accuracy of 0.01gm. The number of test requirements may be 2,3,4 for areas 500, 501-1000,1001-5000sq.ft respectively with an addition of every 5000sq.ft. and acceptable limit of vapour emission rate is 3pounds per 1000sq. ft for 24 hours.

III. MASONRY FOUNDATION STRENGTHENING TECHNIQUES

Almost eighty percent of existing one to three storey building foundations in the developing cities of India is masonry foundation without

reinforcement. The adverse effect on these foundation in flood /earthquake prone area is quite common as these building foundations does not follow the seismic/flood protection measures due to lack of awareness at the time of construction, power and resistance lacking of masonry material against lateral loads. One preventive measures that must be followed in this type of foundation is that proper drainage should be provided in the severe saturation region where the chances of water accumulation below/nearby the foundation.

3.1- Construction of Over slab /Strip Foundation

Though over slab, which consists of overlaying of plain /reinforced slab over the top of the existing foundation with the use of dowel bar or shear studs to ensure the composite action, increase the flexural strength and very much effective in case of foundation possessing reinforcement nearby the overlaying slab but have the drawbacks of increased dead load and more chances of failure due to over reinforcement which becomes severe if the depth of overlay is too deep.

Strip foundations connected at suitable interval on both side of wall and wall heel are constructed to increase the lateral as well as vertical resistance against the load/forces acting on the foundation. The essential requirement of strip foundation is that its base should be on stable ground and height should not disturb the flooring/plinth level. In addition to the all vertical load must be transferred to the ground through old foundation. For connecting new foundation to old foundation minimum reinforcement consisting of round bars with 16 mm dia as main bar and distribution bar of 12mm with 200c/c passing through the old foundation is provided with effective cover of 40mm.In case of non existing of old foundation the reinforcement is connected to the wall plinth. This technique can also applied in case of pedestal through increasing the dimensions and level increase by covering the sides and top provided of the beam reinforcement connected with existing foundation in a symmetric proportion .In the circumstances of neighbor or boundary restrictions one sided strip foundation which looks like a beam on the internal side with pickets fixed at regular interval by destructing some portion of existing wall for interconnection is provided. The construction procedure is same in both cases but in this case the ribbed lateral ties in place of distribution steel is provided.

3.2- Construction of Bigger Foundation Under Existing Foundation

Normally foundations failures are due to the increased soil high pressure caused by earthquake forces and if such symptoms are identified after the earthquake event in the earthquake prone areas ,providing a bigger foundation beneath the existing foundation is an effective solution of the such type of problems as the bigger foundation enables the decrease in the soil pressure by increasing the foundation area. Construction of bigger foundation under existing foundation consists of the following steps:

STEP I-As the new foundation is built slowly and in pieces, the soil under the existing old foundation without affecting the stability of the same is removed.

STEPII-The reinforcement covering the soil removed area with the provision of reinforcement connection to the adjacent part of the portions under construction as well as extension beyond the old foundation required for the new foundation or reinforcement is provided covering the reinforcement of new foundation also soil removed area with provision of extended length of the reinforcement for connection to adjacent part.

STEP III- Either provide support to the portion of soil removed area which have to be taken in the next phase or lift the old foundation through the use of locally embedded jacks under old foundation as per requirement during construction.

STEP IV-Concreting along with layer of expanded concrete or grout of the new foundation under portions of old foundation for which reinforcement activity has been completed is placed.

STEP V-After setting of the concrete the old foundation is placed over the new foundation portion constructed in case of work of other portion construction of foundation is not required lifting of foundation and gaps due to locally embedded jack installation and other gaps if any are filled with rich concrete /pressure grout and jacks are removed .It may be noted that lifting of foundation is not always desirable.

STEP VI-Treating this constructed portion as old foundation, the remaining portion of the bigger foundation is carried out through repeating the above four steps and implementing the steps V after the completion/setting of concrete

This procedure is not only time consuming, having implementation complexity and costly. The another way to apply this technique for foundation strengthening is to provide /embed new foundations each able to withstand itself against tensile and compression forces in both sides of existing foundations inter connected by beams below the foundation or passing over wall over the founation.

3.3- Improvement of Soil Beneath /Around Existing Foundation

Improvement of soil conditions under the foundation through injecting chemical grout in case of soil having clean sand and consolidated injecting

grout/compound prepared with mixing the sand for other soils at regular interval around /below the foundation may be adopted as efficient foundation strengthening techniques if the expansive/collapsible/weak/sodic soil does not exist below/around the foundation. In presence of problematic/weak soil around/under the foundation use of piles/micro piles through combining the old foundation with new foundation enables the soil to bear the load transferred to the foundation.

3.4-Sprayed Concrete/Shotcrete/Guniting

Sprayed concrete also known as shotcrete and gunite is mixture of cement, aggregate and water conveyed through a hose as projected at high velocity/ pressure through nozzle on the concrete surface .Before the spraying of concrete providing anchorage of bar with sufficient anchorage length/steel plates or bolts are fitted with reinforcement or old foundation by removing concrete cover cutting recesses to accommodated. The essential requirement of this type of concreting is that a satisfactory bond between existing and new concrete should form and the whole foundation should be evaluated in the way applicable for reinforced concrete not only but also capability of joint without movement, differences of shrinkage/creep of old and new foundation.

Peeling off shotcrete/concrete due to bond failure without material failure

Involvement of extensive surface preparation and disruption

Requirement of sufficient cross-section capacity to accommodate additional reinforcement without being over reinforced itself

Poor performance in case of congested reinforcement

3.5-Steel Plate Bonding

With the development of epoxy resin/adhesive the steel plate bonding by an epoxy advesive for strengthening the foundation is the flexible, economic, expedient ,versatile and widely adopted technique all over the world as there is no increase in depth and dead weight of the existing concrete member. The success of this technique largely depends upon the interlayer bond between concrete and plate and thickness of the plate as the thick plates are more prone to initiate horizontal cracks and plate separation as compared to thin plates. In case of width thickness ratio less than 50 anchor plates are required as the concentration of high stresses at ends ultimate resulting a premature failure due to increased chances of slip between the reinforcing material and concrete. Selection of a suitable size is must be ensured as the risk of defects increases with width increase. Recent development in this field widely adopted in developed countries is that of the use of external unbounded prestressed tendons but yet it is to be recognize in developing/underdeveloped countries due to its sophistication, requirement of specific skill and experienced designer for handling/application..This method has many advantages such as less susceptibity to weather during execution, non-requirement of surface preparation, easy installation and use of any structural material /contaminated chloride content except only disadvantages of its unsuitability in steel/reinforcement corrosion prone area/foundation.

3.6- Use of Recent Material or Composites /Ferro cement Developed

With the development in the field of plastics and composites in the form of fiber reinforced plastics, ferrocement and glass /armid /carbon fiber composites plates/tendons ,recent techniques of foundation strengthening ,which are either based on strength and fatigue properties of material or derived from the older techniques ,are gaining wide adoptance as a foundation strengthening techniques all over the world. The implementation of these techniques is achieved by two ways i.e. the bonding the prefabricated strips of composite material approximate size 150mmwidth and 3mm thick on the surface of concrete structure and casting of the composite material at site in sheet form of size square /rectangular having dimensions in the range of1000mm-1600mm.Most recent development in this field if that the insertion and bonding with the help of liquid polymer of round or square bar (3-18mm) of composite material either through groove on the surface or making hole .Though composite material may have strength three times more than the steel for same cross-sectional area but it is costlier and breakage/damage is more prone during construction/transportation as compared to steel.

Ferro cement is a form of reinforced concrete utilizing wire mesh as reinforcement and cement sand mortar in ratio 1:2 to produce similar to a fabric of wire mesh packed with coated mortar. This is not the alternative of reinforced concrete but ifs crack control capability due to close / specific spacing of wire mesh and its ability to retain its structural integrity with relatively large strains makes its use as a strengthening material of concrete structures.

IV. CASE STUDY OF SOUTHERN PART OF GORAKHPUR CITY

Foundation problem i.e. developed cracks, tilting of walls, dislocation of building structural component etc based repair/modification techniques are commonly used for the repairs of residential buildings from olden days. Primary cause/source for

the development of foundation/structure problem beyond the control is the natural disaster like earthquake and flood causing moisture variation and soil instability below/around the structure. The study area selected southern part of Gorakhpur city is critical in this context based on its locational features i.e. surrounded by guide bunds of Rapti River, National Highway28 , Ramgarh lake and located at foot hills of Himalaya near Nepal, where more earthquake frequency/chances exists.

For covering the characteristic features of the buildings foundations of the study area ,the different building selected along with details of problems and modifications are summarized in Table 2 on the basis of survey ,observation and information from the occupants:

Table 2- Details of Foundation Problems & Modifications in Study Area

S.No.	Study Area/ Buildings Chararacteristics	Type of Foundation	Symptoms/Remedial Measures
1	Two storey residential building located in Transport Nagar (Low lying area enclosed by Rapti River guide bund and National Highway approx. half Km away from both) having plinth area 2000sq.ft. and was constructed in 2008.	Individual of size 350x250 with trapezoidal footing and plinth beam of 150mm.	Building starts tilting in 2012 and tilting stops in2015 after the addition of R.C.C cross beam through the walls of the foundation inter connected trough perimeter of the building .Presently tilted at an angle of approximately 8 degrees from NW and 6 degrees from NE
2	Only Ground Floor house located in village named Bharawaliya suffers from flood/poor damage problem /water logging almost every year having plinth area 2750 sq.ft. and was constructed in1990 with foundation and slab strengthening in 2015.	Traditional load bearing wall foundation with brick cement sand mortar with RB slab was originally constructed. The foundations were open and plastered with cement coarse mortar and R.C.C slab was provided.	Vertical cracks at corners, doors and joints visible, Sixty percent floor area damaged/undulated. All the cracks were repaired with rich cement coarse sand mortars and flooring as per standard flooring procedure with P.C.C was carried out. Proper apron was provided utilising existing higher plinth.
3	G+1 storey framed structure building located in Mohaddipur with columns &beams on raft covering the plan of the structure	The whole building is constructed with framing of columns and beams in the form of	During Nepal earthquake in 2015 ,the cracks in columns at joint beam & columns, beam sagging/hogging

	consisting of residential accommodation / shops at ground floor and hall supported on columns at first floor Constructed in the year 2013 having raft size40mx15m	panels 5mx4m excluding minor exceptions.	cracks and severe cracks on the centrally located columns at first storey were developed .Columns were strengthened by jacketing /addition of columns
4	Four nos Shops having plinth area 500sq.ft. partly underground(1.60m) and partly over ground (1.50m) space as store located at Pandey Haata was originally constructed in year 2006	Store was constructed with normal masonry work with cement &coarse sand mortar in ratio 1:3 with 12mm plaster in cement &coarse sand in same ratio with addition of waterproofing compound	Excessive moisture presence upto 3ft height in store damaged the floor and plaster almost completely in 8 years inspite of various remedial /preventive measures taken. Hence under ground space was completely filled up and first storey was added in the year 2014

V. CONCLUSION

There are many foundation problem diagnostic techniques and tests as summarized in table (1) that can be used for the purpose of evaluation of the existing foundation and strengthening of the same. Unfortunately no strengthening technique can be applied in all situations as development of different crack /failure pattern at different locations even at similar location/building structure. Individual building evaluation before strengthening is must in case of foundation failure symptoms presence without delay. Though some foundation techniques are costly but avoidance of foundation failure system is not possible for the survival of the structure/serving the purpose as evidenced by building 1, 2, 3 of the case study. Selection / implementation of the technique depends a lot to the experience and no full proof solution is guaranteed due to its dependency as complex variability/nature of soil condition existing below/around foundation, occurrence of different intensity/frequency of natural disasters i.e. flood/earthquake. Even some times cracks in foundation develop at least desirable area that may be due to faulty construction /poor workmanship/quality in original construction. In such cases all the strengthening attempts prove useless as evidenced by building 4 of case study.

REFERENCES

[1]. ACI Committee 437, 1991, Strength Evaluation of Existing Concrete Buildings, American Concrete Institute.
[2]. CPWD Handbook on Repair and Rehabilitation of RCC Structures, Central Public Works Department (CPWD), Government of India, New Delhi, 2002.
[3]. Deputy of technical affairs of technical affairs office, developing the criteria and decreasing the risk caused by earthquake 2006&2007, Seismic rehabilitation guidelines of existing unreinforced masonry buildings. Publication 360&376.
[4]. Developing and promoting the national building regulations office, 2010.Topic 6 of national building regulations (loads applied to building), Tosee-e Iran publications, sixth edition.
[5]. FEMA 273&274, 1997. Nehrp Guidelines for the Seismic Rehabilitation of Buildings, Edition, October.
[6]. FEMA 356, 2000. Pre standard and Commentary for the Seismic Rehabilitation, November.
[7]. Formulation of Guidelines for Assessment of Strength and Performance of Existing

Buildings and Recommendations on Retrofitting Schemes to Ensure resistance to Earthquake, Report No.SSP05441, SERC, Chennai, September 2002.
[8]. FEMA 576, 2006. Techniques for the Seismic Rehabilitation of Existing Buildings, Edition October.
[9]. Guide for Evaluation of Concrete Structures Prior to Rehabilitation (ACI 364. 1R-94(99)), By ACI Committee 364, Rehabilitation.
[10]. Hand Book on Non-Destructive Testing of Concrete, Second Edition, Edited by V.M. Malhotra and N.J. Carino, CRC Press LLC, 2004.
[11]. IS 13311 (Part 1): 1992, Non-Destructive Testing of Concrete – Methods of Test, Part – 1, Ultra Sound Pulse Velocity, Bureau of India Standards and IS 13311 (Part 2): 1992, Non-Destructive Testing of Concrete – Methods of Test, Part – 2, Rebound Hammer, Bureau of India Standards.
[12]. International association for earthquake engineering "A Manual of earthquake resistant non-engineered construction".
[13]. IS 1893,criteria for earthquake resistant design of structures".
[14]. IS 13920-1993, Ductile detailing of reinforced concrete structures subjected seismic forces code of practice."
[15]. J.H. Bungey, 1989, The Testing of Concrete in Structures, Surrey University Press.
[16]. Mohebbi Moghadam B., 2008. Familiarity with methods of seismic improvement of existing buildings. FadakIsatis publications, first edition, spring.
[17]. Non-Destructive Testing of Concrete Structures, Proceedings of the INDO-US Workshop on Non-Destructive Testing, Indian Concrete Institute, Roorkee, 17-18 December, 1996.
[18]. Non-Destructive Testing in Civil Engineering Special Issue, Materials and Structures 38,November 2005.
[19]. Sarmad Nahree. A., Kardan S.M., 2009. Buildings with masonry materials, Azar publications, first edition. Vol. 18 [2013], Bund. Y 5758.
[20]. Tonekaboni Por S.M .2007. Buildings retrofitting principles. Azadeh publications, second edition,

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