DOI will be allocated in final stage GJCEE: May-2021: Page No: 17-26

Global Journal of Civil and Environmental Engineering

Review Article Open Access

Geotechnical Perspective of the Causes of Cracks in Building of University Campus (Sindh University Jamshoro Sindh Pakistan)

Mushtaque Ahmed Pathan[1]*, Maryam Maira[2], Arif Khaskheli[3], Agha Jamshed[4]

[1]Center for Pure & Applied Geology, University of Sindh, Jamshoro
[2]Institute of Environmental Engineering & management, Mehran University Jamshoro
[3]Material Engineer, Prof. Dr. G.B Khaskheli Civil Engineering Lab. Jamshoro
[4]Deparment of Architecture Engineering Mehran University Jamshoro

***Corresponding Author:** Mushtaque Ahmed Pathan**,** Center for Pure & Applied Geology, University of Sindh, Jamshoro, Sindh Pakistan, Email: ma.pathan12@yahoo.com; mapathan@usindh.edu

Received Date: *Apr 26, 2021 /* ***Accepted Date:*** *May 14, 2021/* ***Published Date:*** *May 18, 2021*

Abstract

The Building construction throughout world faces the defects from normal to heavy and destructive like cracks and fractures which cause damages and finally collapse to heavy life losses along with economical and financial. The crack like strictures are found in wall and columns also. For the purpose of study the international experts have classified the minimum allowable standards of these defects which may not be harmful to buildings and people living there. This research study has been carried out to investigate the main reasons to investigate the causes of cracks in a newly completed and used buildings in where some distinct cracks appeared immediately and after some years. Often these cracks seem in almost in walls, columns, beams, and so-like structures having different patterns. The most useful and common methods consisting of reconnaissance survey; building inspection and laboratory testing were used to investigate the causes of these distinct cracks that may lead to the formation of cracks were considered and analyzed by the use of reconnaissance survey, factors like width, pattern, and conditions of the cracks were identified during the building inspection stage and the soil properties related to the creation of cracks were determined during the laboratory test. Based on the results of the study; there was no distinct evidence of factors such as a matured system that may lead to the creation of cracks in the building.

The pore water pressure in this type of soil takes longer time to vanish, which can be expressed by the very low value of the coefficient of permeability (1.90x10-7to2.15x10-7 m/s) acquired from different soil samples collected from the study area. Hence the cracks in this type of building were found to be caused by the settlement of the building due to the nature of the predominant soil type that was found in the study area, all the cracks are active cracks with their width increasing with time and the soils in the entire block of the building possessed high percentage of fine materials with high moisture content and plasticity indices.

Keywords: Buildings; Cracks; Plasticity Indices; Coefficient of Permeability; Pore Water Pressure; Moisture Content; Differential settlement

DOI will be allocated in final stage GJCEE: May-2021: Page No: 17-26

Cite this article as: Mushtaque Ahmed Pathan, Maryam Maira, Arif Khaskheli, et al. 2021. Geotechnical Perspective of the Causes of Cracks in Building of University Campus (Sindh University Jamshoro Sindh Pakistan). Glob J Civil Environ Eng. 3: 17-26.

Introduction

The common imperfections like breaks, cracks and burden settlements are the overall reasons for Building breakdowns wherever on the planet. In Pakistan this danger is likewise destroying numerous little and huge structures in many parts of country [1]. In outcome the deficiency of lives, extreme wounds and tremendous monetary misfortunes like variables. [2]. This issue of building breakdown in our country by and large happens because of utilization of unacceptable proportion of the material in mortar and concrete, low and ill-advised profundity of establishment by some amateurish project workers and so on . Alongside regular perils like flood, plan blemishes and maturing of structures with time. As a typical sign of defilement, wilderness and assumptions that any expert in the constructed climate can accept all structures accountability in a structure interaction without the essential expertise needed for it are considered as another specific factor that generally causes to building disappointment [3].

As per the size, intricacy and motivation behind a specific structure project; the act of planning, developing and working structures is typically an aggregate obligation of various experts and exchanges of development industry [4]. The inexpertness or absence of expert information at least one of those experts may bring about flawed design which can transform into disastrous disappointment. Building breakdown seldom happens without a sign; and the indication of disappointment in building generally incorporate; avoidance of underlying factors and presence of unsatisfactory cracks in certain parts of the structure, and if no appropriate consideration is paid to examine these issues; it might show some part or the entire design unsuitable for its arranged purpose [5].

The cracks or breaks are by and large considered as a sporadic and complete or deficient detachment of the solid into at least two sections, created by breaking or breaking because of the strains that make elastic pressure in overabundance of the limit of material'. The brought about imperfections or breaks present in cement and building dividers is an inborn component, which can't be totally forestalled yet must be controlled and limited by designing techniques [6].

The crevices or cracks are by and large characterized into two significant groups; the primary cracks and non-underlying cracks [7]. Underlying cracks are of genuine concern and ought to be examined, observed, and restored by experts as they can influence the solidness of structures and the harm can be considerable. Some underlying cracks are brought about by numerous reasons and they incorporate; the settlement of the establishment, miss happening of the construction due to over-burdening or plan lack, helpless development strategies/deficiencies in development work, the development of the ground, for example, ground commotion and avalanche, and so forth Also non-underlying cracks are cracks that don't hurt the security of the designs, and they generally results from helpless solid blend, helpless workmanship and development strategies, inappropriate or non development joints and poor primary specifying [8]. Based on development or expansion in size; Cracks can additionally be ordered into dynamic and torpid breaks and the contrast between a

functioning or working crack and a for all time idle break or crack is considered as dynamic air out can or close and get longer, yet a lethargic crack has quite moving. The master thought is vital to separate between these breaks prior to applying suitable answers for the issue [9].

A few soils experienced for designing purposes may have shrinkage/growing possibilities and this property of soils prompts settlement of constructions, the shrinkage/expanding capability of soil is constrained by the earth substance and its pliancy. As a result of that is clayey soils have a high fluid cutoff and pliancy files. Various components cause to establishment settlement and which incorporate; vegetation, ground water bringing down, temperature changes, leakage and scouring, mining subsidence, loss of horizontal help and so on [10]. For the evaluation reason it is vital to consider the reasons for cracks in the structure; the essential boundaries to decide are its area, design, width, length, profundity, age and if it is in real life, how perilous it is and what necessities to fix it [6]. BS 8110 (1997) [8] is particular of the greatest permissible width of cracks in primary components as 0.3mm and 0.1mm for water holding structures. The renowned architect Burland and Day, 1977 gave Classification of cracks dependent on visual harm to the dividers as introduced in table 1.

Table 1: Classification of cracks based on visual damage to walls.

Crack Width (mm)	Category	Classification
Less than 2mm	Very slight	Aesthetic
2mm to 5mm	Slight	Aesthetic
5mm to 15mm	Moderate	Serviceability
15mm to 25mm	Severe	Serviceability
Over 25mm	Very severe	Stability

Source: Burland and Day, 1977 [6]

The maintenance work was finished in the structures of the investigation area were fix prior to giving up of the structure to the various Faculties of and after the structures were involved; yet the cracks keep on existing. Hence this study has been completed to realize the main drivers and careful steps to be taken for security of understudies and staff.

Methodology

The Study Area

The investigation was directed at the Faculty of Natural sciences (CENTER FOR PURE & APPLIED GEOLOGY) single storey building University of Sindh Jamshoro Pakistan. Class rooms, administrator workplaces, labs, and so forth .This structure is situated in a level, low landscape with an upper layer of hard nodular limestone, while the hidden soil is a free shale with silty dirt material. It is situated at Latitude 25025'12.62"N and Longitude 68015'41.86"E. The figure 1 portrays the area of the investigation region. The development of the structure began in 2002 and it was appointed and given over to the Faculty in March 27th, 2006.

The study was divided in three stages; the observation review; (Reconaiance Survey), the structure investigation and lab testing of soil, tests samples collected from the investigation area. The observation study was basic role of examining the prompt climate of the structure in target. Developed trees and waste framework around the area of the construction were observed regarding their effect on the crack advancement on the structure. Four to five spot focuses were chosen during this period of the investigation from where soil tests were collected for research facility testing then the structure assessment was done to analyze the cracks in the structure. Their area, width,

DOI will be allocated in final stage GJCEE: May-2021: Page No: 17-26

profundity and direction. The samples of tests for examination were separated and estimated utilizing the principles of building review. Estimating tape and, protractor were utilized for this reason. The lab tests for soil were led on five soil tests taken from five preliminary pit dove in the examination region. These preliminary pits are meant by STP1, STP2, and so on are signifying the preliminary pits no 1, preliminary pit no 2, etc. The standard profundity of soil tests was 1 to 1.5 m from where the samples were taken and six lab tests were led on each example. The tests were led dependent on the standard strategy and details given in BS 1337 (1990) [11]. Subtleties of the systems for these tests are laid out around there.

The research facility tests for soil tests directed were ordered into; physical and mechanical properties tests. The tests for actual properties were led for the soil classification reason to anticipate the mechanical properties of the soil. These tests incorporate assurance of grain size analysis, Atterberg limits points and Specific Gravity tests. They were directed by the predefined technique laid out in British Standard, BS 1337 Part 2: 1990 (BSI, 1990). The seepage and the solidification tests were conducted as the designing properties tests. BS 1337 Part 5: 1990 while the Consolidation test as per BS 1337 Part 6: 1990 for the Permeability test [11].

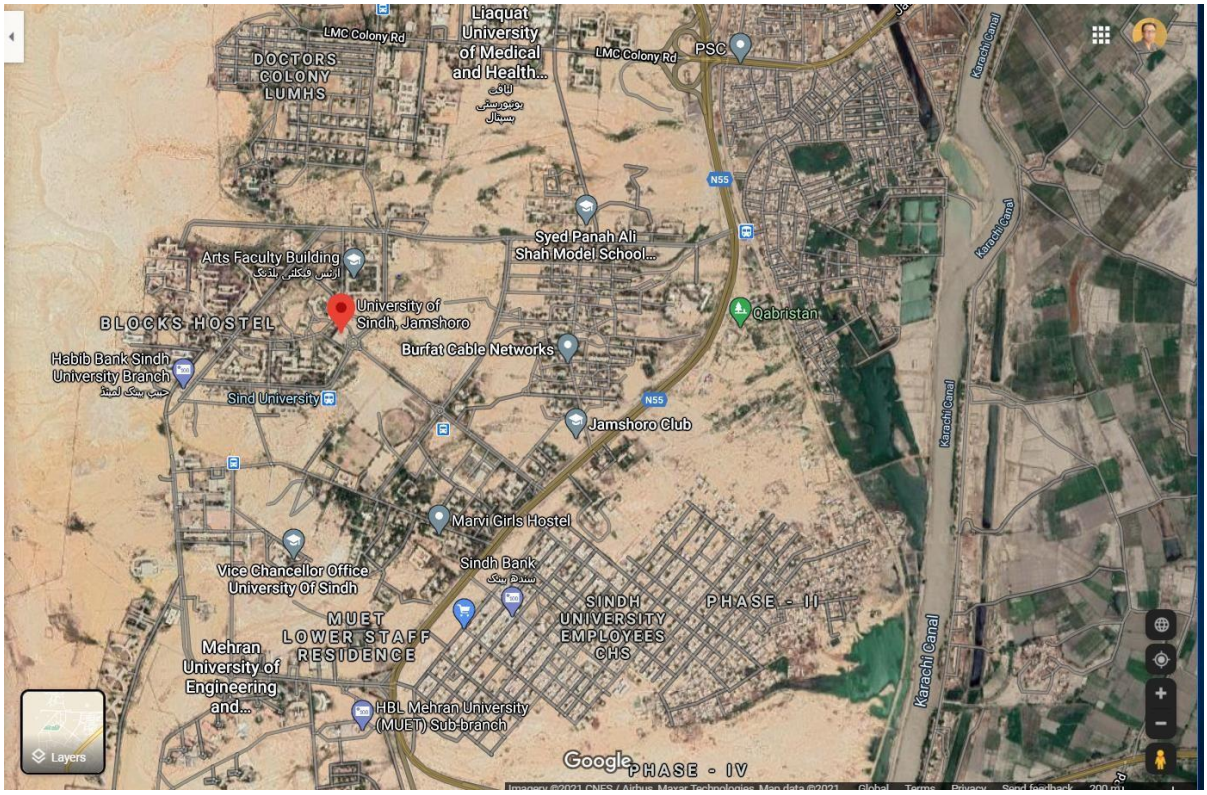

Figure 1: Center for Pure & Applied Geology, University Of Sindh Jamshoro Sindh Pakistan (Study Building) & Satelite Image.

The study was divided in three stages; the observation review; (Reconaiance Survey), the structure investigation and lab testing of soil, tests samples collected from the investigation area. The observation study was basic role of examining the prompt climate of the structure in target. Developed trees and waste framework around the area of the construction were observed regarding their effect on the crack advancement on the structure. Four to five spot focuses were chosen during this period of the investigation from where soil tests were collected for research facility testing then the structure assessment was done to analyze the cracks in the structure. Their area, width, profundity and direction. The samples of tests for examination were separated and estimated utilizing the principles of building review. Estimating tape and, protractor were utilized for this reason. The lab tests for soil were led on five soil tests taken from five preliminary pit dove in the examination region. These preliminary pits are meant by STP1, STP2, and so on are signifying the preliminary pits no 1, preliminary pit no 2, etc. The standard profundity of soil tests was 1 to 1.5 m from where the samples were taken and six lab tests were led on each example. The tests were led dependent on the standard strategy and details given in BS 1337 (1990) [11]. Subtleties of the systems for these tests are laid out around there. The research facility tests for soil tests directed were ordered into; physical and mechanical properties tests. The tests for actual properties were led for the soil classification reason to anticipate the mechanical properties of the soil. These tests incorporate assurance of grain size analysis, Atterberg limits points and Specific Gravity tests. They were directed by the predefined technique laid out in British Standard, BS 1337 Part 2: 1990 (BSI, 1990). The seepage and the solidification tests were conducted as the designing properties tests. BS 1337 Part 5: 1990 while the Consolidation test as per BS 1337 Part 6: 1990 for the Permeability test [11].

DOI will be allocated in final stage GJCEE: May-2021: Page No: 17-26

Results and Discussions

Reconnaissance Survey

Based on starter overview led the outcome shows that the structure was built on a nodular lime stone exceptionally broke development is overlying delicate Shales covered with daintily overlaid residue and mud. There are some developed trees close to the structure which can impact the beginning of the cracks and all the leakage frameworks inside the structure area are few yards and nurseries. Along these lines, the cracks in the structure are brought about by entrance of tree establishes in the structure or in light of water entering into the ground because of absence of appropriate characteristic cracks present in the geographical arrangement grouping.

Building Inspection

As the second phase of the structure review was done by estimating the width, length and direction of the breaks. In this way, beginning toward the start of the investigation the length and width of the cracks were checked and observing exercises were proceeded every hour and then to see whether these two boundaries increments with a hole of time or not. The checking cycle of the cracks demonstrated that the cracks in the structure are dynamic cracks appeared by the presence of new crack edges during the structure review. Major share of these cracks are named extremely serious classified as strength cracks with a normal width more prominent than 20mm [8] in the establishment dividers and more noteworthy than the predetermined 0.3mm on the segments, radiates and the flight of stairs section. This is exceptionally disturbing when contrasted and the most extreme worthy worth given by Burland and Day (1977) and in BS8110 (1997). These cracks are more ghastly on the left hand side of the structure which has more stacking contrasted with the correct hand side of the structure, same as on the ground floor of the structure than on its first floor. These cracks are fast expanding inside and out and width brought about by the settlement of the establishment soil and the conceivable sliding of certain parts of the building /establishment [4]. The flat cracks are wide and of consistent width all through their lengths and appear to have happened simultaneously perhaps brought about by inordinate settlement because of inadequately built establishment and helpless workmanship. Slanting breaks have likewise risen up out of the sides of pillars pocket, entryway and windows edges, and the vertical ones were distinguished. They might be brought about by the progressive vertical development of the establishment and solid shrinkage. The chunk and a portion of the sections additionally endure extreme cracks reaching out through the dividers perhaps brought about by; lopsided settlement in the establishment soil putting the structure under pressure. Figure 2 shows a portion of these cracks.

DOI will be allocated in final stage GJCEE: May-2021: Page No: 17-26

Figure 2: Cracks showing size and orientations in the building.

Laboratory Test Results

The laboratory tests for soil were conducted on both disturbed and undisturbed soil samples collected from the site at a depth of 1 to 1.5m near ground surface. The results of the test result are presented in table 2.

Table 2: Laboratory Soil test results.

TEST	STP1	STP2	STP3	STP4	STP5
Composition					
Gravel (%)	5	4	3	3	4
Sand (%)	13	10	10	12	11
Fine (%)	82	86	87	85	85
Soil Classification BSCS	CI	CI	CI	CI	CI
Uniformity Coefficient U_c	1.6	1.8	1.8	1.7	1.7
Specific Gravity (G_s)	2.60	2.57	2.50	2.75	2.68
Moisture Content w (%)	17	19	20	21	19
Liquid Limit w_L (%)	44.70	44.45	31.50	31.70	38.00
Plastic Limit w_P (%)	22.90	17.10	18.80	15.60	17.40
Plasticity Index I_P (%)	21.80	27.35	12.70	16.10	20.70
Coefficient of Permeability k (10^{-7} m/s)	1.93	1.97	1.9	2.16	2.15
Coefficient of Vol. Compressibility m_v (mm^2/MN)	3.36	3.48	3.34	3.24	3.58
Coefficient of Consolidation c_v (cm^2/sec)	0.23	0.23	0.29	0.17	0.23

Index Properties and Soil Classification

Various file property tests were conducted on the soil samples collected from the site. The soil arrangement was the fundamental actual property of the soil examined in this investigation, relies upon a few factors, for example, as far as possible, specific gravity and grain size analysis. Figure 3 shows a regular grain size dissemination of the soil sample taken from the site. The plasticity index (P I) of the

soil was plotted over the A line [12,13] which is the scope of clayey materials. Along these lines, in light of the British Soil Classification System (BSCS), the soil are named clayey soils of halfway plasticity (CL). The grain size analysis tests demonstrate that the soil contains a high level of fine material running somewhere in the range of 78.18% and 85.57% as shown by the high plastic nature of the soil.

Also, from Table 2, the liquid limit of the soil from the study area ranges somewhere in the range of 28.6% and 45.7%; while as far as possible ranges from 12.3% to 20.8%. The normal moisture content (wn) of the soil samples from the investigation area changes somewhere in the range of 16% and 21%, which is generally high thinking about that the test was conducted in the period of April which is the pinnacle of the dry season around there. The specific gravity of the soil reaches somewhere in the range of 2.60 and 2.70 which are average qualities for clayey soils.

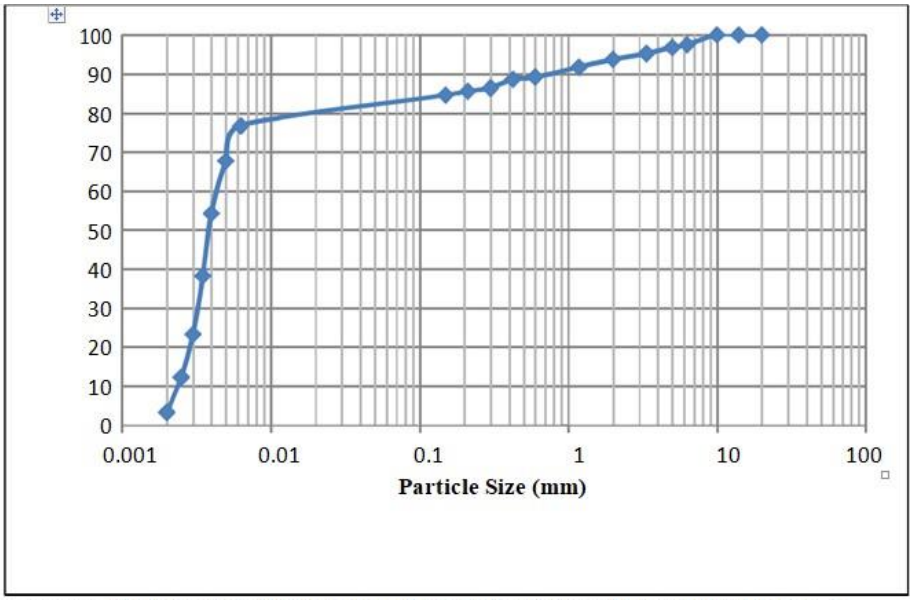

Figure 3: Particle size distribution of typical soil sample from the study area

Engineering Properties

The coefficient of permeability acquired from falling head penetrability test and the coefficient of solidification and volume compressibility got from one-dimensional union tests are the designing properties of the soils observed in this study. The settlement of the building is connected with The properties of the soil to the rundown of the outcomes is given in table 2 and the nitty gritty aftereffects of the one-dimensional group tests are introduced in table 3. The coefficient of permeability of the soil is the pace of stream of water per unit area of soil under a unit pressure driven inclination, and it controls the strength and deformity conduct of soils. The worth of the coefficient of permeability acquired from the soil samples collected from the investigation area ranges between 1.90 x 10-7m/s and 2.15 x 10-7 m/s. These qualities are average upsides of permeability of clayey soils [12]. In light of the lower water driven conductivity worth of the soils the rate of vanishing of overabundance pore water tension on stacking was more slow. The eventual outcomes of a construction worked over soaked soil is the continuous decrease in volume of a completely soaked soil of low permeability because of drainage of a portion of the pore water is a direct result of joint settlement. The coefficient of volume compressibility is utilized to assess solidification settlement. The aftereffects of the

combination tests expect that the establishment soils has high coefficient of volume compressibility [13], generally found in natural alluvial muds (with Mv>1.5m²/MN).

Table 3: Coefficient of consolidation and volume compressibility.

Sample No.	Pressure P(kN/m²)	Settlement ∂H (mm)	Coefficient of Volume Compressibility m_v (mm²/MN)	Average m_v (mm²/MN)	t90 (mins)	Coeff. of Consolidation c_v (cm²/sec)	Average cv (cm²/sec)
1A	25	1.70	3.71	3.54	3	0.17	0.20
1B	25	1.55	3.36		4	0.23	
2A	25	1.64	3.81	3.65	3	0.17	0.20
2B	25	1.60	3.48		4	0.23	
3A	25	1.58	3.54	3.34	6	0.34	0.29
3B	25	1.47	3.14		4	0.23	
4A	25	1.60	3.41	3.24	2	0.11	0.17
4B	25	1.52	3.07		4	0.23	
5A	25	1.68	3.72	3.58	4	0.23	0.22
5B	25	1.54	3.43		4	0.20	

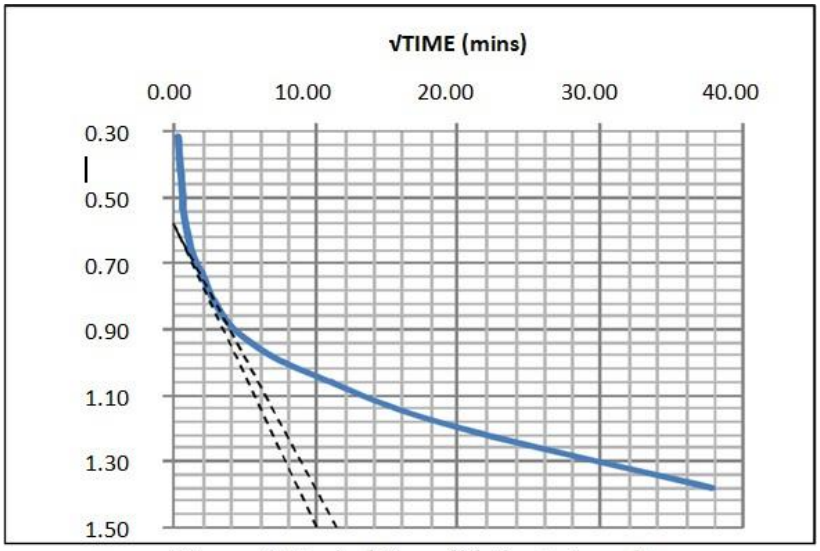

Figure 4: Typical Consolidation test result

Figure 4 shows the coefficient of combination was resolved utilizing the square base of time strategy and a regular consequence of this test. The coefficient of solidification of the soil lies between the scope of 0.23cm²/sec and 0.34cm²/sec which is viewed as moderately low. This is a sign to the poor water driven conductivity of the soil; so the soil will keep on diminishing in volume throughout a significant stretch of time after the fast settlement and might be a few times more prominent than the quick settlement [14-16].

Conclusion

Keeping in view the consequences of the crack investigation; their shape, width and direction and the aftereffects of the soil test conducted on the soil sample from the investigation area it has been presumed that;

A. The subsurface layers include a generally slight top layer of shale store alongside salty and clayey soil. This is underlain by alluvial deposits of salty mud which is covered with nodules of lime stones and coarseness most likely.

B. The cracks are extremely serious containing dynamic and torpid, impacting the primary development of the structure, which are brought about by soil combination under the footings and the establishment dividers; differential settlement of the structure all in all and a helpless establishment plan as well as development technique.

C. The dirt in the establishment contains high measure of earth with high pliancy and poor pressure driven conductivity.

References

1. Boscardin MD, Cording EJ. 1989. Building response to excavation-induced settlement. Journal of Geotechnical Engineering, 115: 1-21.
2. Okada S, Takai N. 2000. Classifications of structural types and damage patterns of buildings for earthquake field investigation. In Proceedings of the 12th world conference on earthquake engineering, Auckland, New Zealand. 30.
3. Son M, Cording EJ. 2005. Estimation of building damage due to excavation-induced ground movements. Journal of geotechnical and geoenvironmental engineering. 131: 162-177.
4. Leonhardt F. 1988. Cracks and crack control in concrete structures. PCI Journal. 33. 124-145.
5. Seralathan B, Selvamsagayaradja M, Murugaiyan DV. 2018. Influence of geotechnical characteristics on cracks in buildings: A case study. International Journal of Civil Engineering and Technology (IJCIET), 9: 1182-1187.
6. Doshi S, Patel D, Patel KB. 2018. Methodology for prevention and repair of cracks in building. GRD Journals-Global Research and Development Journal for Engineering. 3: 52-57.
7. Burland JB, Broms BB, DeMello VFB. 1977. Behaviour of Foundations and Structures: State-of-the Art Report. Proceedings of the Ninth International Conference on Soil Mechanics and Foundation Engineering, Japanese Geotechnical Society, Tokyo. 2: 495-546.
8. BS 8110-8111. 1997. Structural use of concrete. Code of practice for design and construction British standard Institute.
9. Nama P, Jain A, Srivastava R. 2015. Study on causes of cracks & its preventive measures in concrete structures. International Journal of Engineering Research and Applications, 5: 119-123.
10. Bowles JE. 1992. Engineering properties of soils and their measurement. McGraw-Hill, Inc.
11. BS 1377. 1990. Methods of Test for Soils for Civil Engineering Purposes. British standard Institute.
12. Bell FG. 2013. Engineering properties of soils and rocks. Elsevier.
13. Boone SJ. 1996. Ground-movement-related building damage. Journal of geotechnical engineering. 122: 886-896.
14. Dolinar B, Škrabl S. 2013. Atterberg limits in relation to other properties of fine-grained soils. Acta Geotechnica Slovenica, 10: 4-13.
15. Thagunna G. 2014. Building cracks–causes and remedies. In 3rd World Conference on Applied Sciences, Engineering & Technology at Basha Research Centre.
16. Yunusa GH, Hamza U, Abdulfatah AY. 2013. Geotechnical investigation into the causes of cracks in building: A case study. Electronic Journal of Geotechnical Engineering. 18: 2823-2833.