

## Failure of Boundary Walls in Bhopal: An Investigation

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**ABSTRACT :** *In Bhopal, the widespread occurrences of cracking due to alternate swelling and shrinking in lightly loaded structures provided with traditional foundation like the strip footings in are covered by swelling soil. It is likely that foundation movements, due to shrinkage and swelling of expansive soil as a result of moisture content changes are responsible for more damage to building than any other single cause. This forced the Builders and Engineers to take notice and adopt suitable measures to overcome this problem. It relates to light loaded structure that is may not be possible to develop large enough downwards loads to exert the required pressure beneath the supports of the smallest practicable size. Further more, swelling can be prevented only in a localized zone beneath the footing (lying within the bulb of pressure of intensity equal to swelling pressure), where the stresses induced by the foundation are concentrated. The soil beyond the pressure bulb would still swell, and so will the soil in areas between the adjacent footings. The boundary walls are an important part of the building which stride boundary line and used to separate the properties, but it is not a part of building because building has a roof, floor, doors and windows while boundary wall has no such type of arrangement.*

**KEYWORD :** Swelling, shrinkage, settlement, design and quality in black cotton soil.

### INTRODUCTION :

Swelling soil or Expansive soil are those soil which have the tendency to increase in volume when water is available and to decrease in volume if water is removed. Expansive soil is common in Africa, Australia, Indonesia, India, United State, Israel, Burma, and some countries in Europe. In India the area covered by expansive soil is merely 20 percent of the total area and almost the entire Deccan Plateau, western Madhya Pradesh, Chhattisgarh, Part of Rajasthan, Bundelkhand region in Utter Pradesh and part of Andhra Pradesh and Karnataka. In particular swelling soil exist in abundant in arid region and semi arid regions because the low rain fall has not been able to cause the montmorillonite clay mineral to weather into less active clay type nor it has allowed sufficient leaching to carry the clay particles for enough into the lower horizon of soil profile to reduce its affects.

Black cotton soil is mostly residual in character and the thickness of deposit is less than 4 meter. In most cases average thickness is about 1 meter. However, transported soil deposits of Black cotton soil are also known to exist and these deposits can be much thicker, upto 8m or more. In summer season, it is more common to see shrinkage cracks with hexagonal structure, with

vertical cracks as wide as even 10cm, extending upto a depth of 3m or more. The soil are very hard in dry state and posses a high shearing strength which gets reduced appreciably with the ingress of water. The cracks close during wet season and uneven soil surface is produced by irregular swelling and heaving. Such soils are especially troublesome as pavement sub grade or under shallow foundation. The pressure required to prevent expansion due to addition of moisture is the swell pressure. This method of preventing heave is not always successful since the soil stress predicated by the foundation decreases with depth which the swell pressure may not. Its works best when the volume change zone is relatively shallow.

Boundary walls are built last, they got least attention because the private persons are generally built their house first, and afterwards they think about their boundary wall or fencing, according to their availability of money. Boundary walls separate the properties, but it is not part of any building. A garden wall where the wall is astride the boundary line and is used to design of these structures that separate the house from the roads gets little attention. In many cases, cracks develop in boundary walls, due to soil settlement and the vibration of heavy vehicles movement on the road, excessive tree root movement and so on. Generally, the trend is to go for shallow brick footing, or in some cases, a shallow pile foundation with the structure tied up with a plinth beam. The central India is covered mostly with black cotton soil which is highly expansive in nature. The soil expands and shrinks in different season, leading to development of cracks.

Boundary walls include privacy walls, boundary making wall, and city walls. If an exterior structure is made of wires it is generally referred to as a fence while if it is made of masonry it is referred as wall. A common trend for both is barrier, convenient if it is partly wall and partly a fence, e.g. The Berlin wall.

Before the investigation of artillery, many European cities had protective walls. In fact, the English word "Wall" is derived from Latin Vallum, which was a type of fortification wall since they are no longer relevant for defense, the cities have grown beyond their walls, and many of the walls have been turn down. Extreme examples of boundary walls include the Great wall of China and Hand rains walls. A modern functional example was the Berlin wall, which divided Germany. In areas of rocky soils around the world formers have often pulled large quantities of make walls that either mark the field boundary, or the property boundary or both.

Retaining wall is a special type of wall, that may be either external to a building or part of a building, that serves to provide a barrier to the movement of earth, stone or water. The ground surface or water on one side of a retaining wall will be noticeably higher than on the other side.

### FUNCTIONS OF BOUNDARY WALL

Boundary wall is the mark of immovable property by which someone can locate the piece of land belongs to him and to safe guard the property form misuse and encroachment by the others.

### TYPES OF BOUNDARY WALLS

Boundary walls are distinguished according to their height and purpose of use.

**Residential:** The residential building, boundary wall are generally kept 1.5 meter.

**Industrial:** The height of industrial boundary wall is 3.0 meter to 4.0 meter because to save guard the industrial material/product from theft.

**Institutional:** The height of institutional boundary wall is 2.40 meter c.g. Girls Hostel or Working woman Hostels.

**Recreational:** The height of swimming pool boundary wall is 4.0 meter.

**Agriculture:** In country side farmers use to cover their land with the help of barbed wire fencing fixed on wooden ballies of RCC Fencing pole.

**Railway:** In India there is lot of land are kept barrel for railway use railway authorities put their land mark by placing a piece of rails at extreme end of land belongs to them.

**Jail:** The boundary wall of jail building is built with store masonry the height of the wall is usually kept more than 6.0 meter.

**Airport:** The boundary wall of Airport shall be kept not less than 2.70 meter e.g. Boundary wall of Bhopal Airport.

**Park:** The height of the boundary wall of parks are kept 1.50 meter. It is generally made up with partly masonry and partly fencing because un-social elements will not create any hindrance to the public or domestic animals will not destroy the plants and grass grown in the park.

**Religious:** The height of the boundary wall of religious places is 3.0 meter, such as Birla Mandir, or Idgah Wall.

**Fort Wall:** The height of the Fort wall is kept more than 6.0 meter for security point of view. The walls are generally made up with stone masonry with larger area. Now a days fort wall are absolute because they are very thick and they cover much more spaces.

**Nation:** Generally the nation boundary wall made with RCC pole with barded wire fencing, the height of the fencing is 4.0 meter and the boundaries are vigil inspected by the security forces.

### GENERAL CAUSES AND DAMAGES OF BOUNDARY WALLS

- Lack of knowledge, understanding or training in the use of these codes by local engineers.
- Improper detailing of masonry and reinforced structure.
- Poor materials, construction and workmanship used, particularly in commercial buildings.
- Alteration and extension being carried out without proper regard for effects on structure.
- Boundary wall having poor quality foundations or foundations built on poor soils.
- Little or no regularities administering or policing the codes.

### FAILURE OF BOUNDARY WALL

- Unequal settlement of the sub-soil.
- Unequal settlement of masonry.
- Lateral pressure on the wall.
- Lateral movement of sub-soil.
- Due to movement of vegetation.
- Atmosphere action.
- Elastic compression of foundation.
- Slip of foundation structure relative to soil.
- Immediate settlement of surrounding and soil below foundation structure.
- Creep of foundation.
- Primary consolidation settlement of surrounding and soil below the foundation structure.
- Secondary compression of soil below structure.

### REASONS FOR FAILURE OF BOUNDARY WALLS

- ❖ Due to role of sub soil ie swelling or shrinkage
- ❖ Due to improper design
- ❖ Poor Quality of Construction Material

Generally the constructions of boundary walls are not taken seriously and with minimum standards and at shallow depths they will be built. It is in practice that the owner of the building generally will not take suggestion from qualified Engineers and without considering the strength, material and characteristics of

soil construction will be carried out with a local thumb rule methods. As a result, many of the owner's carryout poor methods of construction periodical repairs are required to be carried out. They did not know the characteristics of the soil, and its nature. Due to lack of knowledge, how to carryout proper repairing and strengthening of boundary walls.

### PROBLEMS IN EXPANSIVE SOILS

It should be considered to come out with the choice of appropriate design criteria for careful selection of the proper type of foundation, type of structure and type of construction materials. With proper knowledge of the above indicatives, the potential for structural damage can be dramatically minimized or avoided.

Numerous masonry houses especially lightweight structures on these expansive soils in Bhopal have met with damages originating from differential heave. While the presence of expansive soil in the area can cause significant problem.

Apart from the expansive soil, the defects may originate from inadequate design, poor materials, poor job-site construction or multiple of the factors. In order to understand full the problem behind the poor performance of boundary walls in the case study, a top agenda item is to build-up knowledge of expansive soils both as an entity in its own right, but particularly as a critica component with myriad linkages (Soil-Structure Interaction) to the whole structure, namely foundation and superstructure.

Generally, the structures included both superstructure (walls, floors and roofs) and (substructures foundation and soil). Foundations are in turn divided into two main categories: shallow and deep foundation.

The structures most susceptible to swelling/ shrinkage on expansive soils are those which rest at shallow depths. Damages experienced by these structures include cracks in the foundation and walls. The degree of damage based on observed cracks ranges from hairline cracks, severe cracks, very severe cracks to total collapse.

Apart from the soil and types of foundation, defects can start off from the pitiable design and poor quality of construction materials. Building materials come in many forms, different sizes and different qualities. The problems of heave are more common in un-reinforced concrete or masonry due to their brittleness. The type of as well as standard of material is always behind the poor performance of structures of expansive soils.

The problem of expansive soil caused damages with respect to serviceability in the actual area. If it is from the above facts that the primary goal of this study is to investigate the crucial properties of expansive soil, where the majority of the problems originate, but also on the boundary wall because the magnitude

of the damage is related to the interaction between the soil and the structure.

While very little work has been done to study the extent of expansive soils in Bhopal on one hand, on the other hand the damages in boundary wall founded on expansive soils have been very poorly documented. The scare knowledge about the behavior of foundation in swelling soils is obvious behind the damage of structure supported on the foundations mainly due to the uplift pressure of the foundations following wetting of the soil.

Although the accusing finger is mainly pointed at the expansive soils, other contribution factors such as poor design, poor construction, inadequate observation of the construction processes, poor drainage, trees close to the boundary wall (human activities) and climatic factors have exacerbated the problems.

There are many unanswered questions raised on the origin of the problem whose answer could be provided by practical experiments. The first questions is whether this study could provide a solution to guard against the damages. Another question is whether it is possible to build on expansive soils free of deep-scatted expansive problem.

The origin of the problem is traced back to the pull of towns and cities which have given rise to a growing population in urban areas desire to own shelters. The high demand of accommodation has given opportunity to both homeowners and property speculators a loophole to making profit by providing cheapest and quickest means of accommodation to balance the supply the demand.

### CAUSES OF FAILURE IN BOUNDARY WALLS

1. Inadequate compaction for filled up soil under plinth and foundation bed. This settlement is observed to be non uniform being more under the central portion of the foundation of boundary wall than on the periphery.
2. As per normal practice soil up to at least 1.5m depth is to be partially replaced but in these cases no such replacement of soil was done during construction.

In dry weather, heavier cracks occurred due to shrinking of soil and the soil below foundation settles down because shrinkage is more around the periphery of the boundary wall. Where as in rains, the soil swells up and the movement of soil is in reversed order i.e. swelling is more. Due to this opposite nature of expansive soil, vertical heaving due to absorption of water cause damage to the boundary wall due to settlement.

Man causes of settlement of boundary walls are as bellows:

1. It is observed at the site that absence of apron beside plinth beam causes the free movement of rain water inside the foundation. This caused the soil bulging, piles were tilted.

During summer the soil reduces in volume due to shrinking. Obviously the volume of soil underneath the foundation reduced causing huge settlement.

2. Presence of wild growth and large trees near the plinth. The suction of sub soil moisture by the roots of one or two large trees, affected the foundation and cracks occurred on the surface of the boundary wall.
3. Poor water damage management caused water laying during rainy season. Surrounding the boundary wall. Soil under foundation becomes soft due to absorption of water, causing reduction of shear strength. Consequently, the heaving capacity of soil under foundation becomes low and compressibility increases and settlement under foundation occurred. Water logging in the area added the problem in worst condition.
4. The major cause of distresses on the surface of the boundary wall exists due to presence of expansive nature of soil in around the boundary wall. Other causes which are influencing predominantly the shrinking of foundation are as below:

a) In adequate compaction (bed soil) process had adopted during construction, which makes the loose pockets under foundation and foundation settled.

b) Growth of vegetation, which exists very close to boundary wall, causes the variation of moisture content in sub soil under foundation.

c) Water logging exists during rainy season, causes the variation of moisture content in sub soil under foundation.

d) Rain water enters below foundation due to absence of plinth protection (apron) cause the foundation settlement.

e) Causes of cracks on wall surface, foundation were not extended up to firm strata to counteract the detrimental effect of filled soil. Obviously, the movement caused the diagonal cracks in boundary wall.

f) Improper foundation design-Removal of under laying soil below foundation settlement due to this reason.

- Bhopal is known for its deep black cotton soil area. Soil properties remain plastic and treacherous up to a depth of 6 M. Dr. Dinesh Mohan has carried out extensive investigation of the soil and found that zone of in appreciable ground movement extend up to 2.70 to 3.00 M. Obviously the foundations of all these boundary wall are subjected to horizontal movements of soil and up thrust. That is why boundary wall on road side have settled.

- The soil towards road side remains wet and is not subjected to the same drying shrinkage as the soil towards boundary wall. Road side of boundary wall is the most vulnerable side. As already pointed out, there are accumulation of water during rain at the boundary wall foundation on road side have also settled.

This over saturated situation continuing throughout monsoon has caused disturbances of the founding soil. In face rain water from the campus from factory was flowing at the back of factory and accumulated there till the level raised more than about 2 feet. Then it was flowing out through the syphon below canal.

- The entire campus of the factory suffers from inadequate drainage. On the road side there is Kachha drain. The Cross Drainage of Nalla where it crosses the road is not provided. The entry level of the ground is high & there is poor discharge of rain water. Thus during monsoon the area between the high level road and the factory is full with accumulated water in depression boundary wall of the factory are subjected to this situation.

- Boundary wall of 0.20 m. thick. There are 9 columns in the length of 27.0 m. Being a thick strong wall resting on R.C.C. beam, it shows distress while tilting and collapse.

- Foundation settlement is a common phenomenon in boundary wall in Black Cotton soil area, whatever is the type of foundation. This is caused due to ground movements. The only effective way to deal with the problem is to provide suitable apron around the boundary wall and ensure quick drainage. This would prevent oversaturated condition in monsoon & will also minimize drying shrinkage during dry season. Filling trenches around boundary walls is also another method.

Following observation were recommended during inspection of the boundary wall. Out of all four sides of boundary wall north side/rear side showed distresses as such:-

- Premature deterioration of concrete particularly in columns.

- Shrinking of wall towards inner side.

- Settlement of wall and cracks in walls.

- Unclear area surrounding of the boundary wall and lack of drainage around the wall.

- Stagnation of was has been observed inside the campus, are due to improper slopes and outlets.

- Plinth protection is essential.

- External plaster appears to have been done with Narmada sand. It is deteriorate due to Alkali, Silica reaction. Column and plinth beam are prematurely deteriorated and required immediate attention for enhancing further useful life of structure.

- For 75.85 mt length of boundary wall at least one expansion joint is necessary, where as boundary wall is constructed without any expansion joint.

Additional column are required at expansion joint.

- Trees are spouted from the outer face of wall are need immediate removal of the same.

## CONCLUSION

Detailed investigations and study of boundary walls have brought out several points:

- The expansive soil, when used either as a foundation material or construction material gives rise to many problems in the form of damages to structure. The various damages caused to the boundary walls are mainly due to differential heaving and shrinkage of the foundation soil.
- Based on the various reported case studies and particular observation of the problems of boundary walls, accumulation of water or improper drainage conditions are responsible for failure of boundary walls in expansive soils.
- It has been observed that most of the failure cases of boundary walls are due to improper design of boundary walls, sometimes it is over designed. Problems are also arising due to improper maintenance.
- The methods discussed and analysis in this study are recent ones, rather new, because no work has been done so far to evaluate the failure of boundary walls are recommended for the rational design. However, one has to select the right method, which will be applicable for a particular site condition.
- Knowledge of the precedents, a working knowledge of geology and familiarity with soil mechanics is necessary for successful handling of designs. Experience is a priceless asset of a good foundation engineer.

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