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Research Paper
Available online at: www.jrrset.com
UGC Approved Journal No: 45483
Volume 7, Issue9 Pages 15-21
ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

DESIGN OF RETAINING WALL FOR BRIDGE

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Abstract— Structures which are used to hold back a soil mass are called retaining structures. Our project is to design retaining wall for a minor bridge. As the metro rail project is running through Miyapur, there is a need for the extension of 4 lane carriage way to 6 lane carriage way. But the carriage way includes a minor bridge, which too has to be extended for facilitating the traffic flow. Thus, this project focuses on the design of retaining wall for the modified section of the minor bridge.
Retaining walls are the structures designed to restrain soil to unnatural slopes. They are used to bound soils between two different elevations in areas of terrain possessing undesirable slopes. They are also used in areas where the landscape needs to be shaped severely and engineered for more specific purposes like hillside farming or roadway overpasses. They are also used in bridge abutments and wing walls. The design of structures like retaining wall requires the knowledge of the earth pressure acting on the back of the wall because of the soil backfill in contact with it. Hence relation between the earth pressure on the retaining wall and strains within a backfill is a prerequisite. The project also includes the estimation of safe bearing capacity of soil and its properties, earth pressure calculations and design criteria of a modified section of a retaining wall. The design criteria includes: check for stability against sliding, overturning and bearing capacity.

1.INTRODUCTION

A soil mass is stable when the slope of the surface of the soil mass is flatter than the safe slope. At some locations where the space is limited, it is not possible to provide flat slope and the soil is to be retained at a slope steeper than the surface one. In such cases, a retaining structure is required to provide lateral support to the soil mass. Retaining walls are relatively rigid walls used for supporting the soil mass laterally so that the soil can be retained at different levels on the two sides. Generally, the soil masses are vertical or nearly vertical behind the retaining structure. Thus, a retaining wall maintains the soil at different elevations on its either side. In the absence of a retaining wall, the soil on the higher side would have a tendency to slide and may not remain stable. However for a minor bridge of span 15 m a retaining wall is constructed without considering the slope factor but only the soil properties. The project concentrates on the designing of a retaining wall located on National Highway-9; Pune- Hyderabad via Miyapur. The road in this region is extended for two lanes, from four lane road way to six lane road way to accommodate free traffic flow because of metro railway construction process. The minor bridge located in this region is also to be extended. Thus, our project is been cleared with the design of a retaining wall to this bridge on one side and hence replicating it to remaining. Structures which are used to hold back a soil mass are called retaining structures. Retaining walls, sheet pile walls, crib walls, sheeting in excavations, basement walls, etc., are examples of retaining structures. A retaining wall helps in maintaining the ground surface at different elevations on either side of it. Without such a structure, the soil at higher elevation would tend to move down till it acquires its natural, stable configuration. Consequently, the soil that is retained at a slope steeper than it can sustain by virtue of its shearing strength, exerts a force on the retaining wall. This force is called the earth pressure and the material that is retained by the wall is referred to as backfill. The gravity retaining wall is the simplest type of retaining wall along with other common types of retaining walls such as the cantilever, and the counterfort walls. The design of structures like a retaining wall requires the knowledge of the earth pressure acting on the back of the wall because of the soil backfill in contact with it. 14 The magnitude of earth pressure itself, on the other hand, is a function of the magnitude and nature of the absolute and relative movements of the soil and the structure. Problems such as these, where structure is in contact with the soil mass and the behavior of each one is influenced by that of the other, are classed as soil-structure interaction problems. Often, the earth pressures are statistically indeterminate and hence pose problems in evaluation. In some cases, the desired accuracy in determination cannot be achieved. But knowledge of the relationship between the earth pressure on the retaining wall and strains within a backfill is a prerequisite for the solution of earth pressure problems. The design of the retaining structure requires determination of the magnitude and line of action of the lateral earth

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pressure. The magnitude of the lateral earth pressure depends upon a number of factors, such as the mode of the movement of the wall, the flexibility of the wall, the properties of the soil, and the drainage conditions. It is a soil-structure interaction problem, as the earth pressure depends on the flexibility of the wall. The design has been accomplished with few tests which we have done in the college laboratory. The results extracted were used in the design. The site being in a hard rocky soil strata, we got very high safe bearing capacity. Hence, two more sections apart from actual section according to standard specifications were also evaluated for economic reasons with increased safety factor. The definition of minor bridge, retaining wall and their types, tests and tests results with brief procedure were explained in this report in addition to the safe bearing capacity of the ground, designed sections and their evaluations for safety conditions.

2. SPECIFICATIONS

The work shall be carried out as per M.O.R.T & Hs (Ministry of Road Transport and Highways) • The work will be governed by design considerations & specifications contained in IRC codes of practice for roads/bridges. • The materials of construction shall be governed as per relevant I.S codes. • The grading, size, quality of coarse aggregates shall be strictly as per “Specifications for Road and Bridge works” M.O.R.T & Hs and relevant I.R.C codes. • The size, quality of aggregates and mixing etc for plain concrete and R.C.C works shall be as per “Specifications for Road and Bridge works” and relevant I.S codes

3. PROPERTIES OF SOIL

SAFE BEARING CAPACITY In geotechnical engineering, bearing capacity is the capacity of soil to support the loads applied to the ground. The bearing capacity of soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil. Ultimate bearing 21 capacity is the theoretical maximum pressure which can be supported without failure; allowable bearing capacity is the ultimate bearing capacity multiplied by a factor of safety. Sometimes, on soft soil sites, large settlements may occur under loaded foundations without actual shear failure occurring; in such cases, the allowable bearing capacity is based on the maximum allowable settlement. Terzaghi’s Bearing Capacity theory is used in this project to calculate safe bearing capacity of soil which can be further used to evaluate stability analysis of retaining wall.

4. EFFECT OF WALL MOVEMENT ON EARTH PRESSURE

When the wall is rigid and unyielding, the soil mass is in a state of rest and there are no deformations and displacements. The earth pressure corresponding to this state is called the earth pressure at rest. If the wall rotates about its toe, thus moving away from the backfill, the soil mass expands, resulting in a decrease of the earth pressure. This is a consequence of the 24 mobilization of shearing resistance in a direction opposing the movement of the earth mass. When the wall moves away from the backfill, a portion of the backfill locates next to the retaining wall tends to break away from the rest of the soil mass and tends to move downwards and outwards relative to the wall. Since the shearing resistance is mobilized in directions away from the wall, there is a resultant decrease in earth pressure which continues, until, at a certain amount of displacement, failure will occur in the backfill and slip surfaces will be developed. At this stage, the entire shearing resistance has been mobilized. The forces acting on the wall at this stage does not decrease anymore beyond this point even with further wall movement. This force is called the active earth pressure. On the other hand, if the wall is pushed towards the backfill, the soil is compressed and the soil offers resistance to this movement by virtue of its shearing resistance. Since the shearing resistance builds up in directions towards the wall, the earth pressure gradually increases. If this force reaches a value which the backfill cannot withstand, failure again ensues and slip surfaces develop. The pressure reaches a maximum value when the entire shearing resistance has been mobilized and does not increase any more with further wall movement. This pressure is called the passive earth pressure. The active earth pressure and passive earth pressure develop corresponding to two limiting states of equilibrium. The soil mass is said to be in a state of plastic equilibrium at these two stages. A small increase in stress at this stage will cause a continuous increase in the corresponding strain- a condition known as plastic flow.

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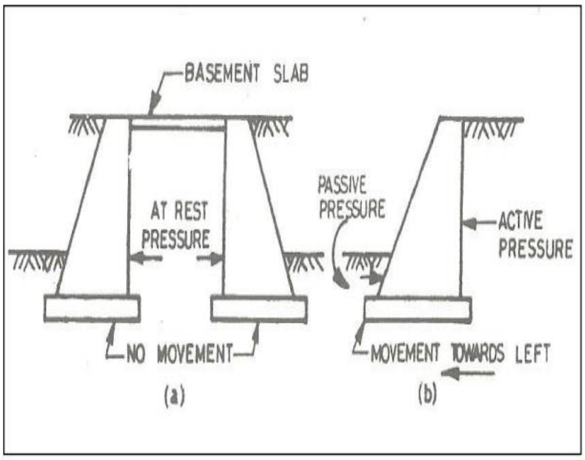


Fig Effect of Wall Movement on Earth Pressure

5. Analysis:

1. Calculate the moisture content of each compacted soil specimen.
2. Compute the wet density in grams per cm3 of the compacted soil sample by dividing the wet mass by the volume of the mold used.
3. Compute the dry density using the wet density and the water content determined in step 1. Use the following formula:

$$\boxed{\gamma_d = \gamma / (1+w)}$$

Where w = moisture content in percent divided by 100, and ρ = wet density

Formulae:

Wet density (gm/cc) = weight of compacted soil/944
Dry density = Wet density/ (1+w)
Where "w" is the moisture content of the soil.

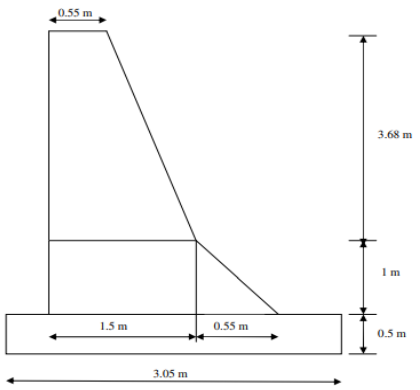
Observations:

Diameter of the cylinder = 10 cm
Height of the cylinder = 12 cm
Volume of the cylinder = 944 cc
Weight of the empty cylinder = 2219 gm

6. DESIGN OF THE RETAINING WALL

By considering the above design procedure and keeping in view of soil analysis, the existing section should be modified and reconstructed. The Existing section of Retaining wall is shown in the figure below

EXISTING SECTION



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TRIAL SECTION 1

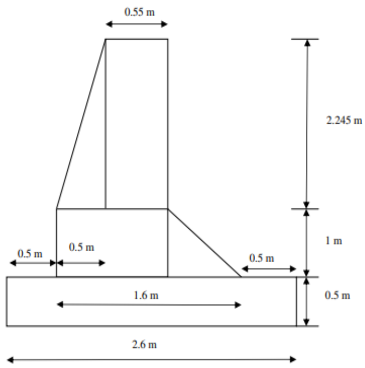

Table no. 5 : load details of the trial section 1

s. no	Components	Load	Lever arm at sill	Moment at sill	Lever arm at floor level	Moment at floor level
I	Above sill level:-					
1	Heel side triangular portion					
	0.50*0.5*2.245*2.3	1.291	0.717	0.926	1.767	2.281
2	Rectangular portion					
	0.55*2.245*2.3 =	2.84	0.275	0.781	1.325	3.763
3	Toe side triangular portion					
	0.5*0*2.245*2.3 =	0	0	0	1.05	0
	Total	4.131		1.707		6.044
II	Below sill level:-					
4	Trapezoidal footing					
a	Rectangular portion					
	1.05*1*2.3	2.415			1.575	3.804
b	Triangular portion					
	1*0.5*1*2.3	0.633			0.867	0.549
5	Final footing					
	2.6*0.5*2.3	2.99			1.3	3.887
6	Weight of earth					
	0.5*3.245*2	3.245			2.123	6.89
	Total	13.414				21.174

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Check for the stresses at sill level:-
x l = ΣM / ΣV
=1.707/ 4.131
= 0.413 m e
= (b / 2) – xl
= (1.05/2) – 0.413)
= 0.112 m b / 6
= 0.175 m e < b / 6
Thus, safe against tension

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Maximum stress, Pmax = (ΣV/b) * (1+ (6e/b))
= (4.131/1.05)* (1+6*0.112/1.05)
= 6.5 t/m2
Minimum stress,
Pmin = (ΣV/b) * (1- (6e/b))
= (4.131/1.05)* (1-6*0.112/1.05)
= 1.32 t/m2 < 53 t/m2 for M20 grade concrete
Factor of safety against bearing capacity,
Fb = qna / Pmax = (66 / 6.5) = 10.15 > 3
Thus, safe against bearing failure
Where qna = allowable bearing pressure.
Check for stresses at foundation level:-
x l = ΣM / ΣV = 15.13 / 9.283
= 1.6 e = -((b / 2) - xl)
= -((2.6/2) – 1.6) =0.3 b/6
= 2.6/6 =0.433 e < b / 6
Thus, safe against tension
Maximum stress, Pmax
= (ΣV/b) * (1+ (6e/b))
= (10.169/2.6) * (1+(6*0.3/2.6))
= 6.042 t/m2 Minimum stress, Pmin
= (ΣV/b) * (1- (6e/b))
= (10.169/2.6) * (1+(6*0.3/2.6))
= 1.098 t/m2 < 53 t/m2 for M20 grade concrete
Factor of safety against bearing capacity,
Fb = qna / Pmax
= (66 / 6.042)
= 10.92 > 3
Thus, safe against bearing failure
Where qna = allowable bearing pressure. Check for sliding failure:-
Fs = μRV / RH
= (0.674*10.169) / 3.245
= 2.11 >1.5
Thus, safe against sliding 75 Where RV and RH are vertical and horizontal reaction forces
μ = coefficient of friction between base of the wall and the soil = tan φ (where φ = 340) Check for overturning failure:-
The wall must be safe against overturning about toe. The factor of safety against overturning is given by
F0 = ΣMR / ΣM0
= 14.248 / 6.89
= 2.073> 2
Thus, safe against overturning
Where ΣMR = sum of the resisting moments about toe.
ΣM0 = sum of the overturning moments about toe

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TABLE NO.7 : LOAD DETAILS OF TRIAL SECTION 2

S. no	Components	Load	Lever arm at sill	Moment at sill	Lever arm at floor level	Moment at floor level
I	Above sill level:-					
1	Heel side triangular portion 0.5*0.5*2.245*2.3=	1.29	0.716	0.923	1.66	2.15
2	Rectangular portion 0.55*2.245*2.3 =	2.839	0.275	0.78	1.225	3.47
	Total	4.129		1.703		5.62
II	Below sill level:-					
4	Trapezoidal footing					
a	Rectangular portion					
	1.05*1*2.3	2.415			1.475	3.56
b	Triangular portion					
	0.7*0.5*1*2.3	0.805			0.716	0.576
5	Final footing					
	2.5*0.5*2.3	2.875			1.25	3.593
6	Weight of earth					
	0.25*3.245*2	1.6225			2.122	3.44
	Total	11.846				16.789

Trail Section 3

TABLE NO.6 : LOAD DETAILS OF TRIAL SECTION 3

s. no	Components	Load	Lever arm at sill	Moment at sill	Lever arm at floor level	Moment at floor level
I	Above sill level:-					
1	Heel side triangular portion					
	0.5*0.5*2.245*2.3 =	1.29	0.716	0.923	1.66	2.15
2	Rectangular portion					
	0.55*2.245*2.3 =	2.839	0.275	0.78	1.225	3.47
	Total	4.129		1.703		5.62
II	Below sill level:-					
4	Trapezoidal footing					
a	Rectangular portion					
	1.05*1*2.3	2.415			1.475	3.562
b	Triangular portion					
	0.5*0.7*1*2.3	0.805			0.716	0.576
5	Final footing					
	2.4 *0.5*2.3	2.76			1.2	3.312
6	Weight of earth					
	0.25*3.245*2	1.622			2.123	3.44
	Total	11.731				16.51

Check for the stresses at sill level:-
x l = ΣM / ΣV
= 1.703/4.129
= 0.412 m e
= (b / 2) – xl
= (1.05/2) – 0.412
= 0.525 – 0.412
= 0.113 m b / 6
= 0.175 m e < b / 6 Thus, safe against tension Maximum stress,
Pmax = (ΣV/b) * (1+ (6e/b))

= (4.129/1.05) * (1+(6*0.113/1.05))
= 6.47 t/m2 Minimum stress,
Pmin = (ΣV/b) * (1- (6e/b))
= (4.129/1.05) * (1-(6*0.113/1.05))
= 1.39 t/m2 < 53 t/m2 for M20 grade concrete Factor of safety against bearing capacity, Fb = qna / Pmax = (66 / 6.47)
= 10.2 > 3 Thus, safe against bearing failure Where qna = allowable bearing pressure.
Check for the stresses at sill level:- x l
= ΣM / ΣV = 1.703/4.129 = 0.412 m e
= (b / 2) - xl = (1.05/2) – 0.412 = 0.525 – 0.412
= 0.113 m b / 6 = 0.175 m e < b / 6
Thus, safe against tension Maximum stress, Pmax = (ΣV/b) * (1+ (6e/b))
= (4.129/1.05) * (1+(6*0.113/1.05)) = 6.47 t/m2 Minimum stress, Pmin
= (ΣV/b) * (1- (6e/b))
= (4.129/1.05) * (1-(6*0.113/1.05))
= 1.39 t/m2 < 53 t/m2 for M20 grade concrete Factor of safety against bearing capacity, Fb = qna / Pmax
= (66 / 6.47) = 10.2 > 3
Thus, safe against bearing failure
Where qna = allowable bearing pressure.

7. RESULTS

The width of the foundation for the third trial section is less when compared to other two sections. Hence, among the three trial sections, the third trial section is economical.

Fig.10.5 Retaining wall being constructed

8. CONCLUSION

The project, designing of retaining wall for a minor bridge is the consequence of prestigious metro rail project. In the construction course of metro railway, a four lane road way has to be extended to six lanes, to avoid the occurrence of traffic problems. The minor bridgein this course also has to be extended. We took existing four lane retaining wall as an example and designed retaining wall for the six lane road way. Each section has been analyzed for failure against sliding, overturning, tension and bearing capacity. After doing trials for many sections, we got a section satisfying all the safety conditions, approximating the standard dimensions of a gravity retaining wall. The location of minor bridge being in rocky strata, with moorum soil, we got a high bearing capacity value. Taking this as a reference, we also designed two economical sectionswith reduced dimensions. Hence, apart from the main modified section other two sections can also be considered to make the project economical, which is the main philosophy behind the project.

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