A FINITE ELEMENT PERFORMANCE BASED APPROACH TO COMPARE THE STABILITY OF PRECAST RETAINING WALL WITH CONVENTIONAL RETAINING WALLS

A
THESIS

Submitted in partial fulfilment of the requirements for the award of the degree
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Under the supervision
of
Mr. Chandra Pal Gautam
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by

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

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HIMACHAL PRADESH, INDIA

May-2019

STUDENT'S DECLARATION

I hereby declare that the work presented in the thesis entitled **"A finite element performance based approach to compare the stability of precast retaining wall with conventional retaining wall"** submitted for partial fulfilment of the requirements for the degree of Master of Technology in Civil Engineering(structural engineering) at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Chandra Pal Gautam.** This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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10 May, 2019

CERTIFICATE

This is to certify that the work which is being presented in the thesis titled **"A finite element performance based approach to compare the stability of precast retaining wall with conventional retaining wall"** in partial fulfilment of the requirements for the award of the degree of Master of Technology in Civil Engineering(structural engineering) submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Rohit kotwal (172653)** during a period from August, 2018 to May, 2019 under the supervision of **Mr. Chandra Pal Gautam,** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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ABSTRACT

In conventional approach of constructing the retaining walls, there are several disadvantages like more construction time, cost, manpower and environmental impacts makes these conventional methods ineffective and uneconomic. In this project precast concrete wall system is proposed which includes two components. One is cantilever retaining wall panel and other is base slab. This precast cantilever wall is connected to the base slab through headed anchors which bonds the wall and slab and make them intact in their respective places. These two components are casted offsite in a well-controlled manner so that maximum quality can be achieved and then transported to the construction site. This system needs a unique method of construction for the final assembly. For analysis, two steps are followed in this project. First, design the different components i.e. toe slab and stem heel etc, for shear force and bending moments and other step is to evaluate the stability of complete structure below the service loads including the overturning. sliding and bearing failure. For the precise analysis, Abaqus which is finite element-based software, is used in this work. These different walls i.e. conventional retaining walls (cantilever and gravity walls only) and precast concrete retaining wall are modelled and analysed for stability in Abaqus software. This comparison shows whether precast retaining walls are best replacement for conventional retaining walls or not.

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CHAPTER 1

INTRODUCTION

1.1 General

Structure which holds the soil, water or any other materials in their actual position so that erosion of these materials does not occur is known as retaining wall. Some places where slope is so high, geographical conditions do not the mass to remain in its natural slopes. These materials which are hold by retaining walls is called backfill. Stabilizing hillsides and control erosion are the main functions of retaining walls. During the roadway construction sometimes, it is necessary to construct these structures where there is over rugged terrain with steep slopes. These walls decrease the grades and land requirement alongside the roads. In some cases, there is a lack of land available besides the travel way then retaining walls become necessary to allow acceptable slope conditions and for safer construction. In those cases where slopes are quite steep, soils are unstable or heavy runoff occurs these walls help to stem erosion.

1.2 Types of retaining walls

In this present time, there are different kinds of retaining walls used which are classified on the basis of their shape, material used, resisting action or casting methods etc. Some of these conventional retaining walls are:

1) Cantilever type retaining wall
2) Gravity type retaining wall
3) Buttress/Counterfort retaining wall
4) Anchored retaining wall
5) Piled retaining wall
6) Crib retaining wall
7) Gabion retaining wall

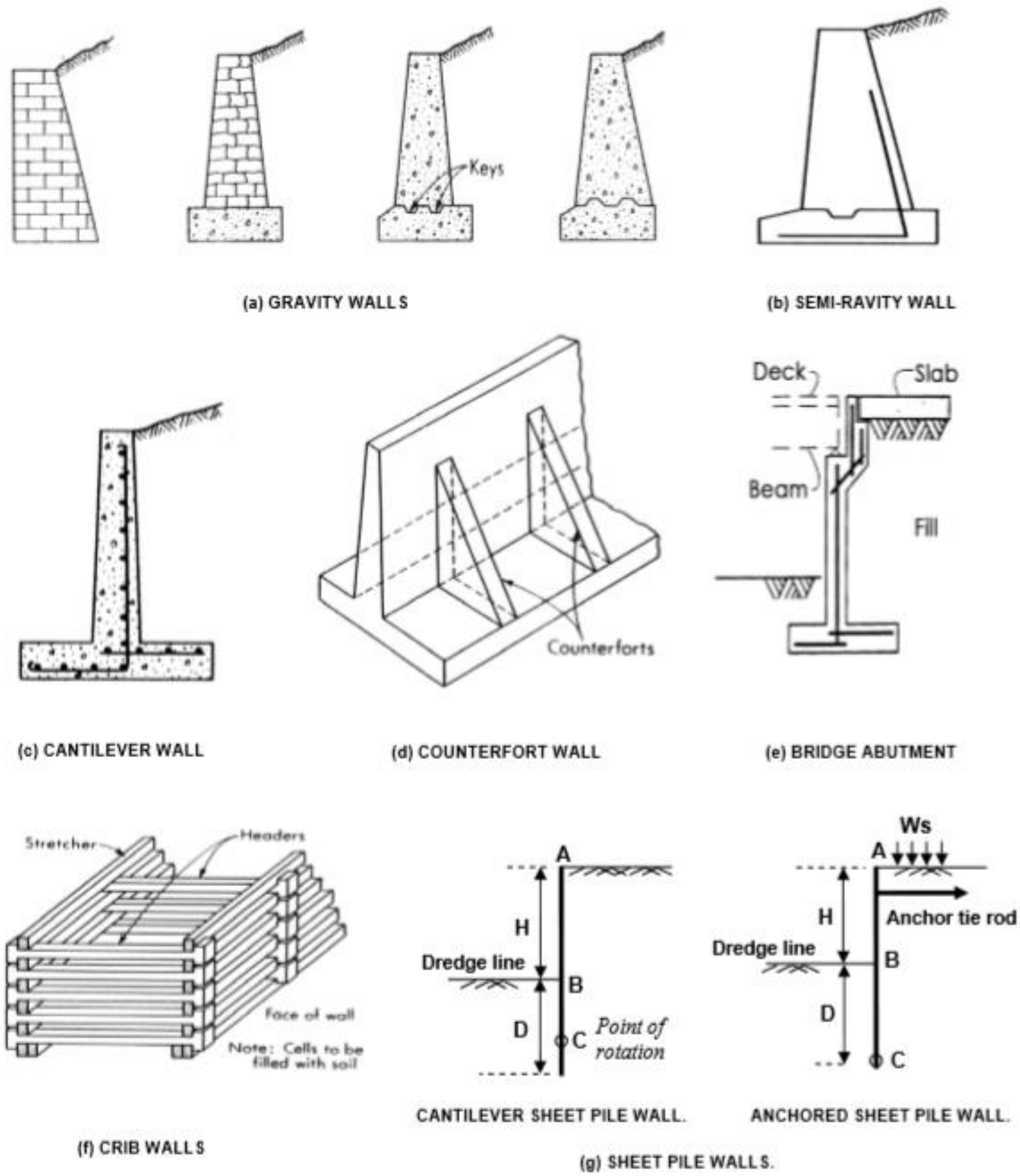


Fig 1.1 *Different types of Retaining wall*

1.3 Cantilever retaining wall

Cantilever retaining walls are usually of reinforced concrete and these are inverted T like structure. It works on the principles of leverage. It has basically three parts which are (i) stem (ii) heel slab (iii) toe slab. These walls have much thinner stem and use the weight of the backfill soil which provides the most of the resistance to sliding and overturning. These walls are shown in figure given below. Up to the height of 6 to 7m, these walls prove economical. Each of the components are designed as cantilever. The stability of the wall is partially provided by the weight of earth on the heel. Sometimes these walls are constructed in the form of L shape. Key, a vertical projection is given below the base of the wall to increase the resistance for sliding. In this project first a cantilever retaining wall is designed with some given parameters in excel format and the its stability is analysed by using Abaqus software.

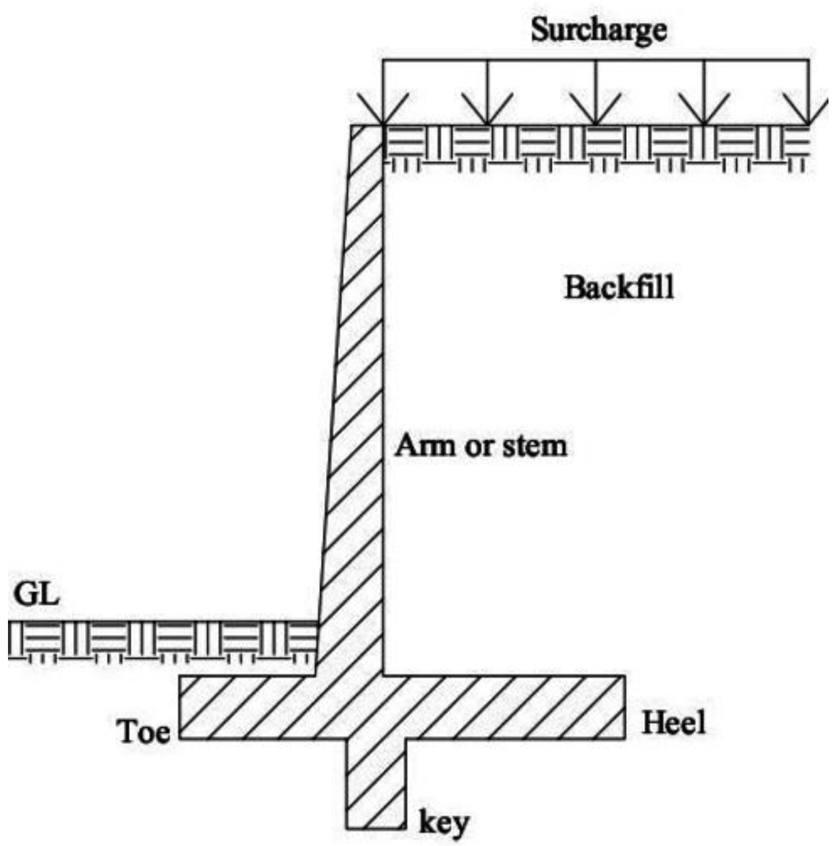


Fig 1.2 *Components of cantilever retaining wall*

1.4 Gravity type retaining wall

In these types of retaining wall, the basic mechanism used to retain the backfill or fill materials which resist the earth pressure by virtue of its own self-weight. These are basic and simple structures either made of concrete or stones which are available locally. These walls can be casted into any shape or size followed by proper design procedure and specifications as recommended by codes. However, these walls also prove uneconomical beyond the height of 6m. The main reason of this limitation is the requirement of large base widths. These walls are designed only for static loads and seismic forces are not considered in it because it is easier to repair the damaged walls. In this project also, this wall is designed for only static loads. But in actual practice, design work is also based on site conditions and the provisions given in standard codes. There are also different considerations like foundation needs, drainage through stones etc. which advances the working of these walls and proper provisions are also considered in design. A typical gravity type retaining wall is shown in figure below.

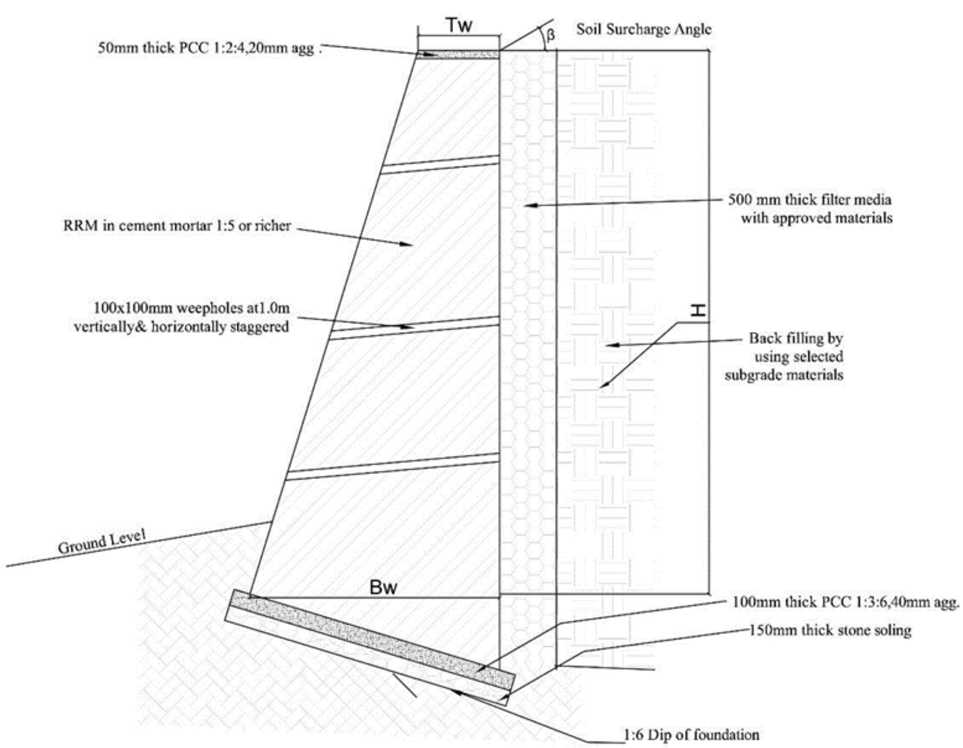


Fig 1.3 *Components of gravity type retaining wall*

1.5 Precast concrete retaining wall

In this method RCC retaining walls panels made of concrete is made in production line condition and afterward transported to site. These walls are made in industrial facility according to the required measurements and then transported to site for development. Retaining wall panels are produced in a controlled condition therefore quality can be maintained effectively. If there are large structures to be constructed than precast concrete proves to be the cheaper form of construction. Example of these walls are shown in figure 1.4 given below.

Fig 1.4 *Applications of precast retaining wall*

1.6 Advantages of precast retaining walls

This precast wall system has many advantages over conventional retaining walls. These are:

1. **Rough and Tough**

   If we compare this to other materials, over the time, strength of precast concrete retaining walls gradually increases. The main problem with these materials is, they can lose strength, degrade, face creep, stress relaxation and get deflected over the time. When heavier loads like vehicular impacts and other live loads acts on them, they may not be able to resist. The load-carrying capacity this wall comes from its own structural properties. Quality of these walls do not depend on the of the surrounding backfill quality or its own structural strength.

2. **Quality**

   Precast retaining wall sections typically are made in a different casting area in controlled plant environment therefore they exhibit uniformity and high quality. The main advantage of these precast sections are the factors which affect the quality, naturally found on job sites like curing situation, material quality, temperature and poor craftsmanship are nearly removed in a plant environment where casting is done.

3. **Erection**

   To set a precast concrete retaining wall panel into its place is easier as it does not need superior rigging to avoid structural damage. therefore, precast concrete retaining walls are less liable to vibratory damage while it is backfilled with the surrounding soil. As a result, backfilling operations can usually proceed much faster around precast concrete structures.

4. **Resistant to weathering effects**

   Design mix which are used to cast precast concrete retaining walls can be adjusted to withstand estimated corrosive agents, as we know no material is completely resistant to chemical attack. Different materials like steel and other materials get rapidly deteriorate in the presence of corrosive agents, some in the presence of water alone

5. **Best design**

   Precast concrete retaining walls are generally supported by engineering specific to both the particular wall system and to the project site conditions. This is not always the case with walls built from natural stone materials (i.e., boulders).

6. **More durable**

   Precast concrete retaining walls are usually made from wet-cast, air entrained concrete that is very durable. Resistance to the adverse effects of repeated freeze-thaw cycles and road salts can be significant. Check with the producer to verify the mix design used (including the strength of the concrete) and to verify that the producer has a Quality Assurance program in place.

7. **Best in appearance**

   Many of the precast concrete retaining walls are made with an architectural finish that replicates natural stone. In addition, precast concrete walls can be stained with a number of commercially available stain products to further enhance and customize the look.

8. **Green and economic**

   Besides water, concrete is the most used material on earth. It is nontoxic and environmentally safe. Precast structures are modular, can fit any design situation, are produced in a quality-controlled environment and are ready to install immediately upon arrival at the job site. Precast retaining wall components are easily produced to be durable during storage and transportation

   1. easy to install
   2. Less vulnerable than competing products to damage during backfill
   3. Environmentally safe during operation.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Survey

Ali Ghanbari and Mahyar Taheri [1] conducted from their study concluded that precise calculation of active earth pressure subjected to the effects of surcharge which is acting on the backfill, is very important aspect in many geotechnical problems. In this project author used analytical methods to calculate the stresses due to line surcharge acting on backfill materials. The old horizontal slices method is rechecked and new formulation of this method is proposed. This new invention helps to find the effect of line surcharge on retaining walls either friction or cohesive frictional backfills. The procedure of this approach is calculating lateral pressure acting due to the surcharge without reinforcement and then comparison is made with other techniques. Finally, new method which is used to determine the effects of internal friction angle and cohesion on active earth pressure from the line surcharge outcomes of this approach.

Anne-Sophie Colas et. al. [2] research is based on the behaviour of dry-stone retaining wall when loaded with gravel up to its failure limit. As we know dry stone walls increases the aesthetics of the landscapes and in past few decades, they are used all over the world. There are many scientific studies launched to develop modelling and simulations related to structures made of dry-stone masonry. However, few experimental data are present till now to validate and to calibrate these simulations. In this approach a 2.5m high wall is used to find the results in which this wall is backfilled with gravel and is observed until its failure point.

Colas AS et al. [3] aims at the contribution to the building of dry-stone masonry by using a simple model which is based on homogeneity and yield design. A new analytical expression to calculate the ultimate load is determined. To validate this method comparison with the distinct element method, limit equilibrium analysis and field trails are done as we observed, there is an increase in construction of drystone walling that preserves existing structures but also to build the new one. However due to the lack of scientific data and information to access its reliability the expansion of dry-stone walling is slowed down.

Caltabiano et.al.[4] introduces a new approach which is founded on the virtual static equilibrium of soil wall system. As the usage of the pseudo static methods, calculation of soil thrust under seismic condition acting on the retaining wall are well established in the design work. The most common method is derived from the theory made by two researchers Okabe & Mononobe. Also, in last 20 years different methods are also developed which are based on the limited displacement idea but there is a shortcoming in these methods. In the new result the effect of presence of the wall is considered and directly applied to wall systems with surcharge backfill. There are formulae to calculate the yield acceleration. Also, inclination of the failure surface can be found directly

D. Shinde [5] replaced the old design of conventional retaining walls with new one by providing the relief shelves on the backfill side of the retaining wall. These types of walls are known as retaining walls with relief shelves. These shelves make the wall to resist the lateral earth pressures acting horizontally and increase the overall stability. As a result, an economical design is obtained which uses less material as compared to massive cantilever walls without the shelves. After the study it is concluded that at the height of 0.4h to 0.5h best location is found where reduction of active earth pressure, bending moments and minimum deflections happens. It is found that 41.50% deflection is reduced by providing these shelves at 0.5h than deflection without shelf given. Deflection of the stem increases if shelf is located from 0.2h to 0.8h. so we can say deflection of stem depends upon the shelf location.

Fuente et al. [6] in their study presents three innovations which are associated to precast concrete panels which is used in reinforced earth retaining walls. It also concerns the anchor system of the panels and the set-up of the pull-out test to evaluate the effectiveness of the anchors and use of fibres which acts as reinforcement. From all experimental work and results obtained, viability of this approach has been proven. From this study advantages of these approaches regarding performance and production process are found.

Jozef Vlcek [11] in his work monitored that there is an important difference between measured and assumed values of axial forces and displacements in geosynthetic reinforcements. Because of the conventional approach for old analytical methods and high safety factors. undervalue their parameters related to strength. As strength parameters are not fully achieved, properties related to deformation of geosynthetic reinforcements and its interactions with soil become more significant. In this paper wall displacements, strains and axial forces in reinforcements by the use of analytical and numerical methods are shown.

Klonarisb et al. [18] conducted in the designing of rigid gravity and cantilever walls which acts against the earthquakes, mostly limiting-equilibrium Mononobe– Okabe type solutions are preferred widely. A different approach which follows the analytical work of Younan & Veletsos have been given which is elasticity-based solution. A more all-purpose finite-element method of solution is presented in this work whose results shows to agree with the available analytical results. To briefly examine parametrically the effects of flexural wall rigidity, this method is employed. Both inhomogeneous and homogeneous retained soil is considered in this approach while for foundation of the retaining system, introduction of second soil layer is required in this approach. They show the useful effect of soil inhomogeneity at the same time.

M.D. Bolton [14] tries to find out the best and economic way to design the retaining walls and he concludes that the safe and economic design depends on the proper utilization of strength in the soil. He found that the dense soil is brittle in nature and loses its strength under strains well-matched with the predictable displacements of wall. Loose soil fails to fully achieved its accessible strength. The concept of mobilizable soil strength is used which offers a scientific and logical basis to helps in the design work of all structures related to geotechnology.

Mundell C et.al [13] works on the performance of dry stone walling up to its failure under the action of load as we know dry stone wall construction is an old form and is used worldwide. However, for their analysis a very little research has been conducted due to which it become difficult to analyse these structures. In this paper author used four numbers of full-scale drystone walls which were constructed and tested to failure in a test laboratory for further investigation. Many typical swelling patterns are found in many in situ walls reconstructed through the course of testing. In this paper the detail description of instrumentation and setup for the laboratory is given.

S. Bali Reddy & A. Murali Krishna [20] discussed in their study that under the effect of static and seismic loading. Backfill soil is used in retaining walls affect the overall performance. Granular cohesionless backfills are the best option among all the choices preferred. But there are also many are materials which are lightweight like fly ash, plastic bottles, shredded tire chips, geofoam, etc which acts as a backfill materials in the present time. Benefits of such type of backfills are they help to reduce the earth pressure and adjacent displacements of the walls. Every year scrap tyres amount is increasing which is an undesired urban waste and also in future its amount will be increase to large extent. Somehow if we reuse these scrap tires in the applications of highway engineering this will be an essential step to make a sustainable future. By using these scrap tyre derivative materials offer greater economy as compared to traditionally used materials. All properties of the scrap tire chips are evaluated by many researchers. Sand tyres chip mixtures are tested by conducting direct shear tests, permeability, triaxial tests and compressibility on samples has been done.

Tamadher Abood et.al. [21] designed a cantilever type retaining wall in this paper which is made of concrete and steel reinforcement. This wall has the shape like an inverted T. A detailed analyses and design for this type of walls are presented. It also includes the estimation of primary dimensions of the wall, which were checked later. Factor of safety plays a significant role in the analysis of these structures. Calculation of factor of safety against sliding, overturning & bearing pressure were also done. According to ACI codes calculation of shear resistance for the base, tension stresses in the stem and base and reinforcements for each part were done. We know retaining structures hold back soil or other loose materials where the change in ground levels is so abrupt. These structures hold the backfill pushes it back but also tends to overturn or slide which cause the failure of these structures.

Zastrowa et al. [22] in his paper some walls assessment of 30 retaining walls are done having various heights in Spain. This study also involved different permissible soil stresses i.e. 0.2,0.3 and 0.4 MPa. This study involved with the environment impacts which were taken in the assessment method and are analysed for the case which shows the impact of the wall height and allowable soil stress. These are developed by Leiden university. Also, the second part is to find the contribution range of elements to each impact. Concrete, transport landfill, formwork, machinery, and steel are these elements which are used here. Impact factors for per unit of steel, formwork and concrete are provided in this approach.

2.2 Research gap

Most of the retaining walls have been constructed using conventional methods and casting techniques. There are very few methods available for the usage of precast retaining walls due to the lack of scientific research and information. Detailed experimental study of the precast retaining walls have not done yet in the applications of highways and bridges as a result, these precast retaining wall systems are not all over the globe.

2.3 Research objectives

1. Designing of conventional (cantilever and gravity type only) and precast retaining walls to evaluate the overall stability.
2. Analysis of the above-mentioned retaining walls using ABAQUS software to find out whether precast retaining wall is an effective and economic replacement for conventional retaining walls or not.

CHAPTER 3

METHODOLOGY

3.1 Procedure to be followed

In this project, two conventional retaining walls are considered i.e. cantilever type retaining wall and gravity type retaining wall which are designed for the same parameters and same backfill conditions. Their design process involves the selection of dimensions, according to the specifications given in various codes and then their overall stability is calculated when backfill load acts on them. After that for the same loading conditions, a precast retraining wall panel is designed and their stability with respect to overturning and sliding is determined. All three mentioned walls then analysed in Abaqus software, which is a finite element-based software and their behaviour is studied there. The design work is based on the calculation of stability of the complete structure under the action of service loads and overturning, sliding and bearing failure modes are also considered in the analysis. The main objective of this project is to find the suitability of precast retaining wall as a replacement for the conventional retaining walls.

The flow diagram of the work methodology is shown below.

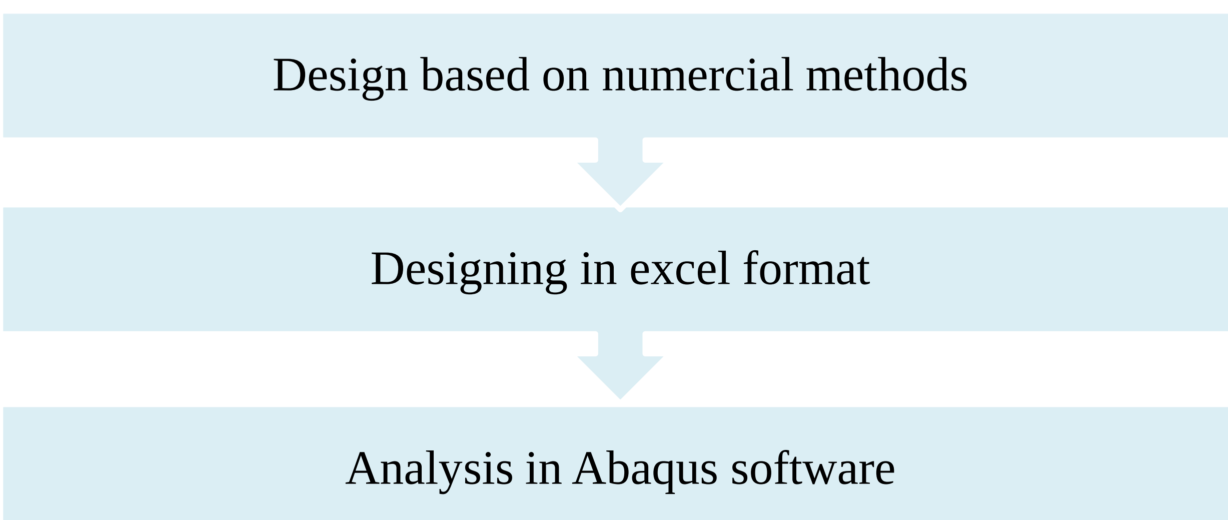


Fig 3.1 *Flow chart for project work*

3.2 Design calculations for cantilever retaining wall

Input data (N.subramanian, 2015) for the designing of cantilever retaining wall is given in table 3.1.

Table 3.1 *Design parameters for the cantilever retaining wall*

Sr.no.	Parameters	Notation	Value
1	The height of wall	h	3.8m
2	The density of back fill soil	ϒs	18kN/m^2
3	Angle of repose	ϕ	30^0
4	Angle of surcharge	β	15^0
5	Concrete density	ϒc	25 kN /m^2
6	Safe Bearing Capacity of underneath soil	SBC	150 kN/m^2
7	Friction co-efficient between soil and concrete	μ	0.5
8	Concrete grade used	f_{ck}	25 N/mm^2
9	Steel used	f_y	415N/mm^2
10	Factor of safety		1.5
11	Effective cover		50mm

3.2.1 Preliminary dimension calculations

Foundation depth

D_{min} is the minimum depth of foundation as per code

$D_{min.} = SBC/\gamma\ [Ka]$ (as per IS 456:2000)

$175/18*[1/3]^2 = 1.08m$

Provide depth of foundation as 1.20m

Over all height of retaining wall= 5.5+1.2=6.70m

Base width

For T shaped retaining wall, min. base width is calculated by formula

$b = \sqrt{3P\ 2\gamma}$

$P = 1/2* Ka * \gamma * H2$

$=1/2*1/3* 18 * 6.72 =134.67kN$

$b = \sqrt{3*134.67\ 2*18} =3.35m$

Consider toe width $=1/3b$ = 1/3*3.35= 1.12m

Provide toe width = 1.20m

Total base width =4m

Base slab thickness = $H/12$ to $H/15$

In between 0.558 to 0.446

Consider uniform thickness = 500mm

For stem

Pressure at the base of stem $=Ka * \gamma * h$

Here h= 6.70-0.50 = 6.20m

Max. moment at the base of stem= $(1/2* Ka * \gamma * h2) * h/3$

$= 1/2*1\ 3* 18 *6.203\ /3= 238.32kNm$

Factored moment $=1.5 * 238.32 = 357.48$ kNm

For Fe 415 steel

$Mu = 0.138 * fck * b * d2$ (As per SP 16, Pg 10)

$357.48 * 106 = 0.138 * 20 * 1000 * d2$

d = 359.89mm

consider 50mm effective cover

Total d for stem required = 359.89+50 = 409.89mm

Provide total depth of stem = 450mm

Provide top width of stem = 0.20m

For heel and shear key

Width of heel = 4.00-1.20-0.45=2.35m

Provide shear key of size 450*500mm below base to prevent sliding of the wall.

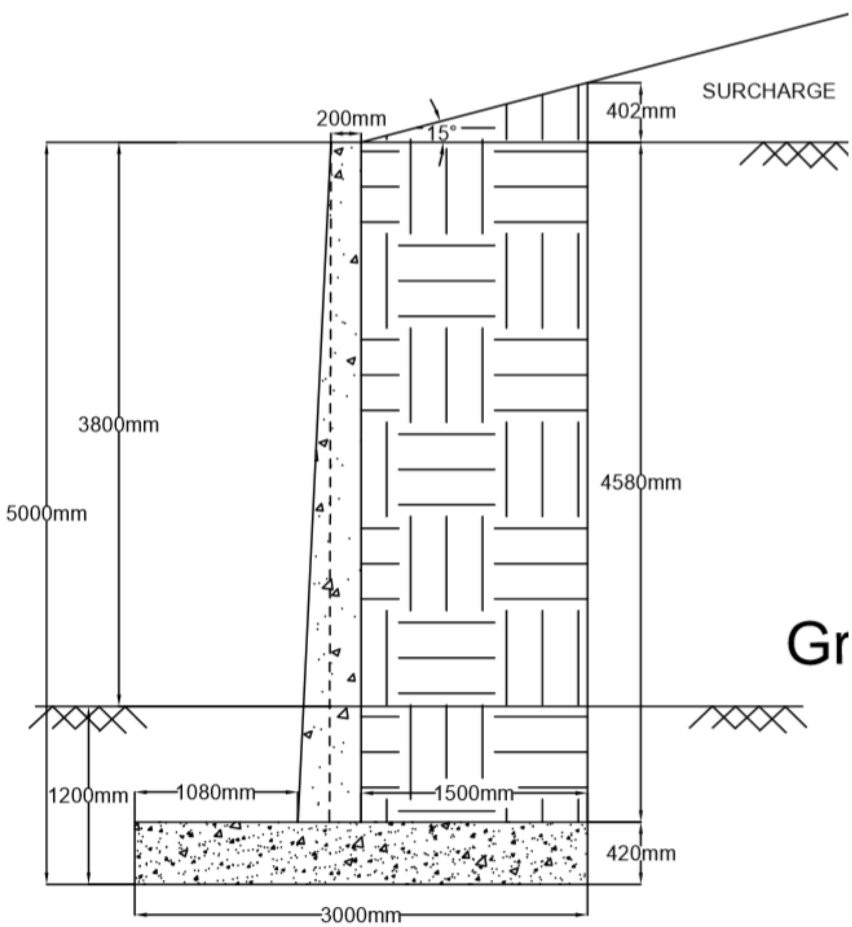


Fig 3.2 *Final calculated dimension of cantilever retaining wall.*

3.2.2 Loads and moments calculation

All the service loads acting on the retaining wall either in horizontal or vertical direction are calculated in the table 3.2 and 3.2 respectively.

Table 3.2 *For horizontal loads*

Load	Horizontal load (kN)	Perpendicular distance from A (m)	Moment about A (kNm)
Active earth pressure	1/2∗ 40.2 ∗ 6.7 = 134.67	6.7/3= 2.23	300.31
TOTAL	**134.67**		**300.31**

Table 3.3 *For vertical loads*

Load	Horizontal load (kN)	Perpendicular distance from A (m)	Moment about A (kNm)
Stem W1	6.20 ∗ 0.2 ∗ 25 = 31	1.2 + 0.25 + 0.1 = 1.55	48.05
Stem W2	1/2∗ 0.25 ∗ 6.2 ∗ 25 = 19.375	1.2 + 2 3 ⁄ ∗ 0.25 = 1.37	26.54
Base slab W3	(4.0 ∗ 0.50) ∗ 25 = 50	4 /2= 2.0	100.00
Shear key W4	(0.45 ∗ 0.50) ∗ 25 = 5.625	1.2 + 0.45 2 ⁄ = 1.425	8.02
Backfill W5	(2.35 ∗ 6.2) ∗ 18 = 262.26	1.2 + 0.45 + 2.35 2 ⁄ = 2.825	740.88
Total load ∑W	**= 368.26 kN ↓**		**∑M=923.49kNm**

Total downward load = 368.26 kN

Resisting moment = 923.49 kNm

3.3 Checks for factor of safety

Let distance of CG of all vertical loads from the face of the toe i.e. From A

$\sum W = \bar{x}$ = Net moment at A (toe)

$\bar{x} = (923.49 - 300.31)/368.26 = 1.69$m

Hence eccentricity (e) = $b/2 - \bar{x} = 4/2 - 1.69 = 0.31$m

Max. pressure at A (Toe)

$P_{max} = \sum W/b\ (1 + 6e/b) = (368.26/4)\ [1 + 6*0.31/4] = 134.86\ kN/m^2 < 175$ (SBC). *Hence safe*

$P_{min} = \sum W/b\ (1 - 6e/b) =$ 368.26 4

$[1 - 6*0.31/4] = 49.25\ kN/m^2 > 0$

P_{min} is greater than 0, it means no tension at base. *Hence safe*

Factor of safety against overturning

Resisting moment =923.49kNm

Overturning moment =300.31 kNm

Factor of safety = 923.49/300.31 = 3.07 > 1.55 $safe$

Factor of safety against sliding

Sliding force = 134.67 kN

Frictional force=$\mu * \sum W = 0.5 * 368.26 = 184.13$kN

Passive pressure under the base of key

$P_p = Kp * \gamma * h1 = 3 * 18 * 1.0 = 54$kN as (h1 =0.5+0.5 = 1m)

$\therefore$ Total $P_p = 1/2 * 54 * 1.0 = 27$kN

FS = restoring force / sliding force = 211.13 / 134.67 = 1.57 > 1.55, *hence safe*

3.4 Design of gravity type retaining wall

The Input parameters for the design of gravity retaining wall is shown in table 3.4.

Table 3.4 *Input parameters for design purpose*

1	The height of wall	h	3.8m
2	The density of back fill soil	ϒs	18kN/m^2
3	Angle of repose	ϕ	30^0
4	Density of masonry	΄ϒm	24 kN/m^2
5	Safe bearing capacity of soil below the footing	SBC	150kN/m^2
6	Coefficient of friction between concrete and soil	μ	0.5
7	Angle of surcharge	β	15^0

3.4.1 Dimension calculation

In this step, base and top width of the wall is calculated form the design table shown in fig.3.4 according to their respective height.

					Surcharge angle upto 15⁰		
		SBC 80		**SBC 100**		**SBC 150**	
sl no	**Height**	**Base width**	**Top width**	**Base width**	**Top width**	**Base width**	**Top width**
1	1	0.5	0.45	0.5	0.45	0.5	0.45
2	2	0.9	0.5	0.9	0.5	0.9	0.5
3	3	1.55	0.5	1.55	0.5	1.55	0.5
4	4	2.2	0.6	2.2	0.6	2.2	0.6
5	5	3.85	0.8	3.5	0.8	2.65	0.8
6	6	4.9	1	4.7	1	4.1	1

Fig 3.3 *Design standard with surcharge load*

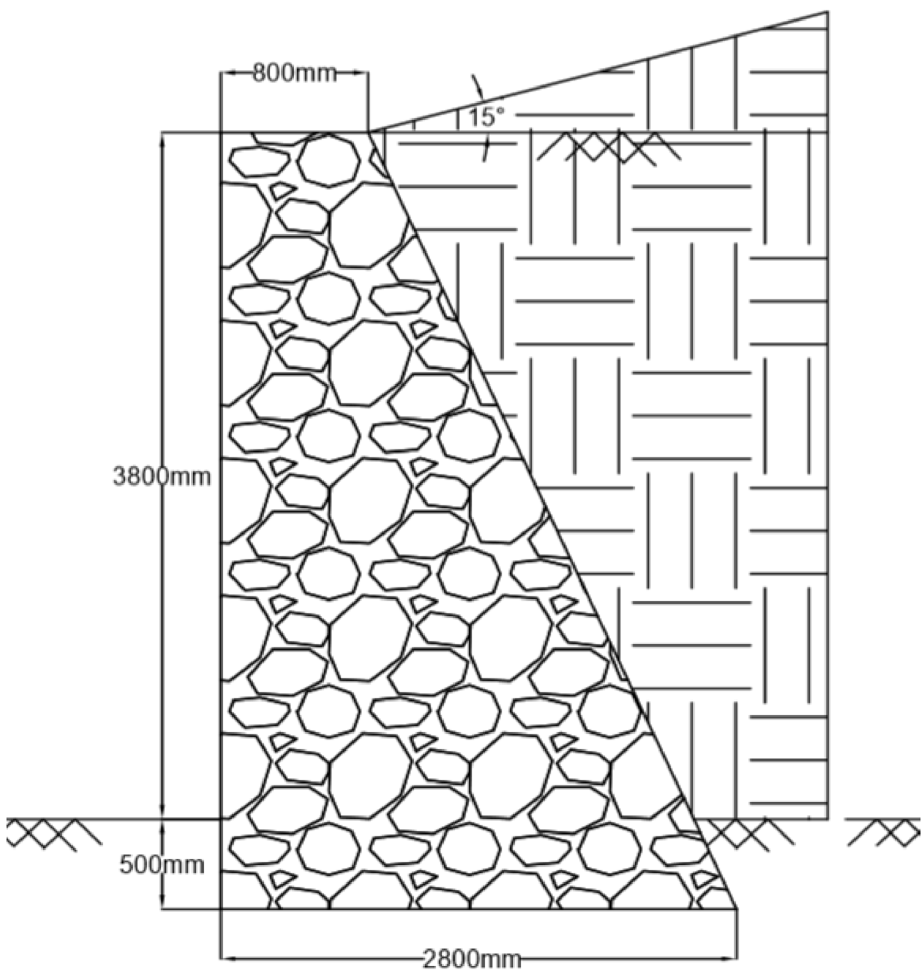


Fig 3.4 *Final calculated dimensions of gravity retaining wall.*

3.4.2 Loads and Moments calculation

In these walls all service loads are resisted by the self-weight of the wall. Weight of the wall acting in vertical direction is the only resisting force to all service loads. In my case the calculation of these forces is shown in table 3.4. Active earth pressure Ph= ($Ka*\gamma*H^2/2$) and it acts at H/3 height from base of the wall**.**

Table 3.5 *loads and moments calculations*

Sr. no	**Load name**	**Magnitude of load (kN)**		**Toe distance (m)**	**Bending moment about the toe (KN-m)**	**Remarks**
1	W 1	0.8*4.3*24	57.60	2.4	198.144	
2	W 2	0.5*(2.8-0.8) *4.3*24	103.2	1.34	138.29	
	∑W		**185.76**		**336.43**	
	$\sum M_R$		**336.43**			
	P_h	$P_h = Ka*\gamma* H^2/2$	59.95	1.43	**85.93**	**M_O**

3.4.3 Checks for safety factors

For overturning

$\sum M_R / Mo \geq 2.0$ where, $\sum M_R$=Total restoring moment

Mo =Overturning moment

= 336.43/ 85.93= 3.92

Hence safe

For sliding

$(\mu * \sum W) / Ph \geq 1.55$ where, $\sum W$ = Total load acting vertically

= (0.5*185.76) / 59.95 = 1.55

μ = coefficient of friction

P_h= active earth pressure

Hence safe

For bearing pressure

x = (Resultant moment at toe) / $\sum W$

(336.43-85.93) / 185.76 = 1.35m

$e = (B_w/2)-x$ where, e = is eccentricity

= (2.8/2) -1.35=0.05m

B_w is base width

$P_{max} = \sum W/b\ (1+6e/b)$ — P_{max} the maximum pressure at the toe

= (185.76/2.8) [1+(6*.05/2.8)]

= 73.66kNm < **SBC**

Hence safe

$P_{min} = \sum W/b\ (1-6e/b)$ — P_{min} is the minimum pressure at the toe

= (185.76/2.8) [1- (6*.05/2.8)]

= 59.03 kNm > **0**

Hence safe

3.5 Proposed precast retaining wall

For replacing the conventional retaining walls, a precast retaining wall system is proposed which is shown in figure below. In this design there are two parts (i) levelling pad (ii) precast wall panel.

Levelling pad

This section is an inverted L shape .one arm acts as shear key and other acts as levelling surface for the wall panel. Dowels or anchor bars of 25mm dia. are also embedded into the vertical arm.

Precast wall panel

It is also L shape structure having heel slab in horizontal direction and stem in vertical direction. Holes are provided at the bottom part for the embedment of dowels. there are also attachments for the fixature of geogrids and geomembranes.

In this wall the overturning moment is opposed by the heel slab and geomembranes. And sliding is resisted by the dowels and shear key provided at the bottom of the precast wall panel.

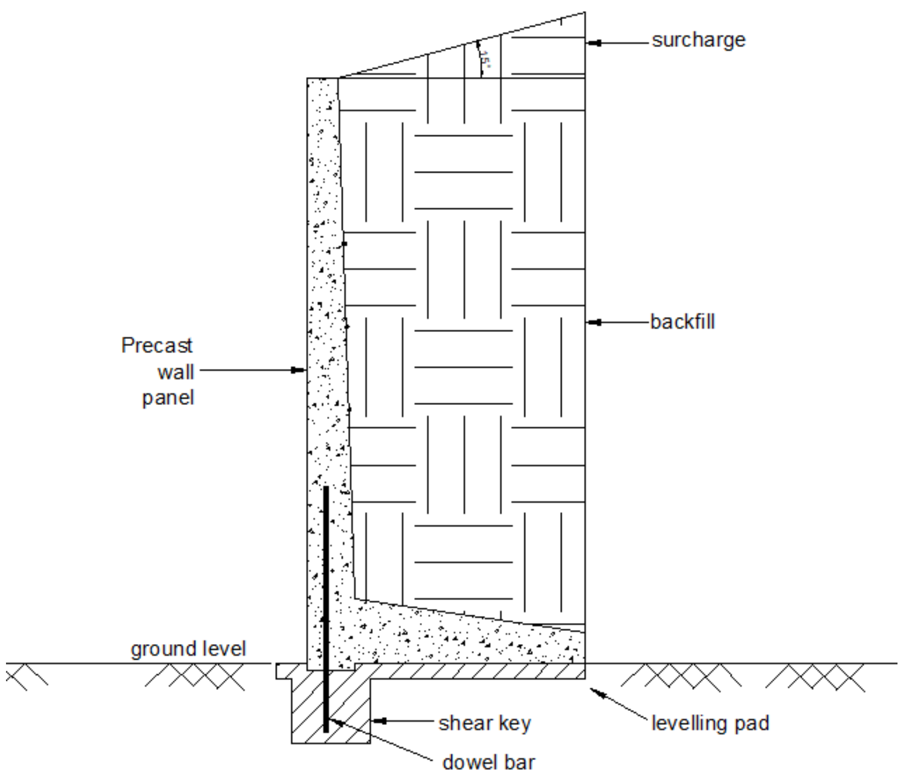


Fig 3.5 *Proposed precast cantilever retaining wall panel*

3.6 Designing done in Excel Format for cantilever retaining wall

Preliminary dimensions calculation

Data input					
Sr. No.	**Data**	**Symbols**	**Quantity**	**Units**	**Remarks**
1	Height of wall above ground level	h	3.80	m	
2	Safe bearing capacity of soil	SBC	150.00	kN/m^2	
3	Density of soil	ϒ	18.00	kN/m^3	
4	Angle of surcharge	β	15		
5	Cofficient of friction between concrete and soil	μ	0.5		
6	Angle of repose	ϕ	30	degree	
7	Concrete grade	fck	20	N/mm^2	
8	Steel grade	fy	415	N/mm^2	
9	Density of concrete	f_{ck}	25.00	N/mm^2	
10	Factor of safety		1.50		
11	Effective cover		50	mm	

Fig 3.6 *Entry table for various parameters used for the design of cantilever retaining wall in excel sheet*

Preliminary Dimension calculations					
Sr. No.	**Data**	**Symbols**	**Quantity**	**Units**	**Remarks**
	Total earth pressure	P	75.00	kN	
	cofficient of active earth pressure	Ka	0.333		
	cofficient of passive earth pressure	Kp	3		
	Foundation				
1	depth of foundation	df	0.926	m	as per IS 456:2000
2	total height of retaining wall	H	5.00	m	
	Base slab				
3	width of base slab (min.)	b	2.500 3.500	m	0.5H to 0.7H
4	thickness of base slab		0.417	m	H/12
5	heel width		1.500	m	
6	total base width	b	4.00	m	
	Stem				
7	height of stem above base slab		4.58	m	
8	pressure at the base of stem		75	kN	
9	Max. moment at the base of stem		96.072	kNm	
10	factored moment		144.108	kNm	
	for fe 415 steel				As per SP16,Pg 10
11	min thickness Mu=0.138*fck*b*d^2		229	mm	
12	thickness at base		0.279	m	assume
13	width of stem at top		0.139	m	
	shear key				
14	width of key		0.420	m	
15	depth of key		0.420	m	
			0.5		
			0.268		

(a)

Final Dimensions				
Sr no.	**name**	**symbol**	**calculated dimensions (M)**	**final dimensions (M)**
1	depth of foundation	Df	0.926	1.200
2	height of wall above ground level	h	3.800	3.800
3	total height of retaining wall	H	5.000	5.000
base slab				
1	total width	B	3.000	3.000
2	thickness	Tb	0.417	0.420
3	**HEEL** slab width		1.500	1.500
4	**TOE** slab width		1.080	1.080
Stem				
1	total height from base slab		4.580	4.580
2	thickness at base level		0.279	0.420
3	thickness at top level		0.139	0.200
Shear key				
1	Width of key			0.400
2	depth of key			0.300

(b)

Fig 3.7 *(a) calculation of preliminary dimensions for retaining wall (b) final dimensions table*

3.7 Stability Calculation

Stability calculations

1	Density of soil	Υ	18.00	kN/m^3		
2	Angle of surcharge		15			
3	Angle of repose	ϕ	30			
4	cofficient of active earth pressure	K_A	0.373			
5	cofficient of Passive earth pressure	K_P	3.000			
6	height of surcharge upto heel slab		0.402	0.4		
7	total height including surchare slope	H'	5.400			

Sr.No.	Load types	notation	load (KN)	perpendicular distance form toe end (m)	moment about A (kNm)	Remarks
	for horizontal loads					
1	Active earth pressure		94.542	1.80	170.18	
	Total load $\sum W$		**94.542**			
	Total moment $\sum M_r$		**170.175**			
	For vertical loads					
1	Footing	W1	31.500	1.500	47.250	
2	Rectangular portion of wall	W2	22.900	1.600	36.640	
3	Triangular portion of wall	W3	12.595	1.773	22.335	
4	Soil on heel	W4	123.660	0.750	92.745	
5	soil in inclined slope	W5	5.400	0.500	2.700	
	Total		196.055		201.670	
	Total load $\sum W$		**196.055**			
	Total moment $\sum M_r$		**201.670**			

Fig 3.8 *Sheet for calculation of overall stability of retaining wall*

3.8 Checks for Factor of Safety

Check for stability			
Types	**Values**	**Units**	**Remarks**
Max. pressure below the base slab (**P_{max}**)	117.2	kN/mm^2	< *SBC,safe*
Min. pressure below the base slab (**P_{min}**)	13.51	kN/mm^2	> *0 , safe*
Check for overturning			
stabilizing moment	386.49	kNm	
overturning moment	170.18	kNm	
factor of safety	2.04		*≥1.4 , safe*
Check for sliding			
sliding force	94.542	kN	
frictional force	98.028	kN	
factor of safety	1.037		*≥1.4 , safe*
shear key calculation			
	magnitude	**units**	**remarks**
width of shear key	0.4	m	assume
depth of shear key	0.3	m	
distance of shear key from toe	1.1	m	
depth of foundation	1.2	m	
Distance from bottom of base slab to ground level (h1)	0.9	m	
b	0.635	m	
Passive pressure below the toe	69.05	kN	
factor of safety against sliding new	**1.59**		*≥1.4 , safe*

Fig 3.9 *Various checks on retaining wall*

3.9 For gravity retaining wall

Design of Gravity type retaining wall					
SR NO.	DESIGN PARAMETERS	SYMBOLS	MAGNITUDE	UNITS	REMARKS
1	Height of wall from ground level	H'	3.8	m	
2	Depth of foundation	D_f	0.5	m	as per code IS 14428
3	Total height	H	4.3	m	
4	Base width	B_w	2.8	m	
5	Top width	T_w	0.8	m	
6	Unit weight of soil	Υ_s	18	kN/m^3	
7	Unit weight of masonary	Υ_m	24	kN/m^3	
8	Angle of repose	ϕ	30	degree	
9	Cofficient of friction	μ	0.5		
10	Safe bearing capacity	SBC	150	kN/m^3	
11	Angle of surcharge	β	15	degree	

Fig 3.10: *Excel sheet for dimension calculation of wall*

H	I	J	K	L	M
CHECKS					
1	For overturning	**ΣM_R / M_0**	3.92	***≥ 2.0***	**safe**
2	For sliding	**$\mu \Sigma W$ / P_H**	1.55	***≥ 1.55***	**safe**
3	For overall stability				
1	CG of all forces from Toe **(x)**	**(ΣM_R.M_0)/ΣW**	1.35		
2	Ecentricity **(e)**	**(b/2-x)**	0.05		
3	Max. pressure below the base slab **(P_{max})**	**(ΣW/b)*(1+6e/b)**	73.66	***< SBC***	**safe**
4	Min. pressure below the base slab **(P_{min})**	**(ΣW/b)*(1-6e/b)**	59.03	***> 0***	**safe**

Fig 3.11: *Excel sheet for checking of stability of wall*

CHAPTER 4

SOFTWARE ANALYSIS

4.1 Introduction

Abaqus is a finite element-based software which involves various steps to carry out the complete analysis. These steps are:

1. Geometry or modelling
2. Assigning the material properties
3. Applying loads and boundary conditions
4. Meshing of model
5. Analysis
6. Post processing

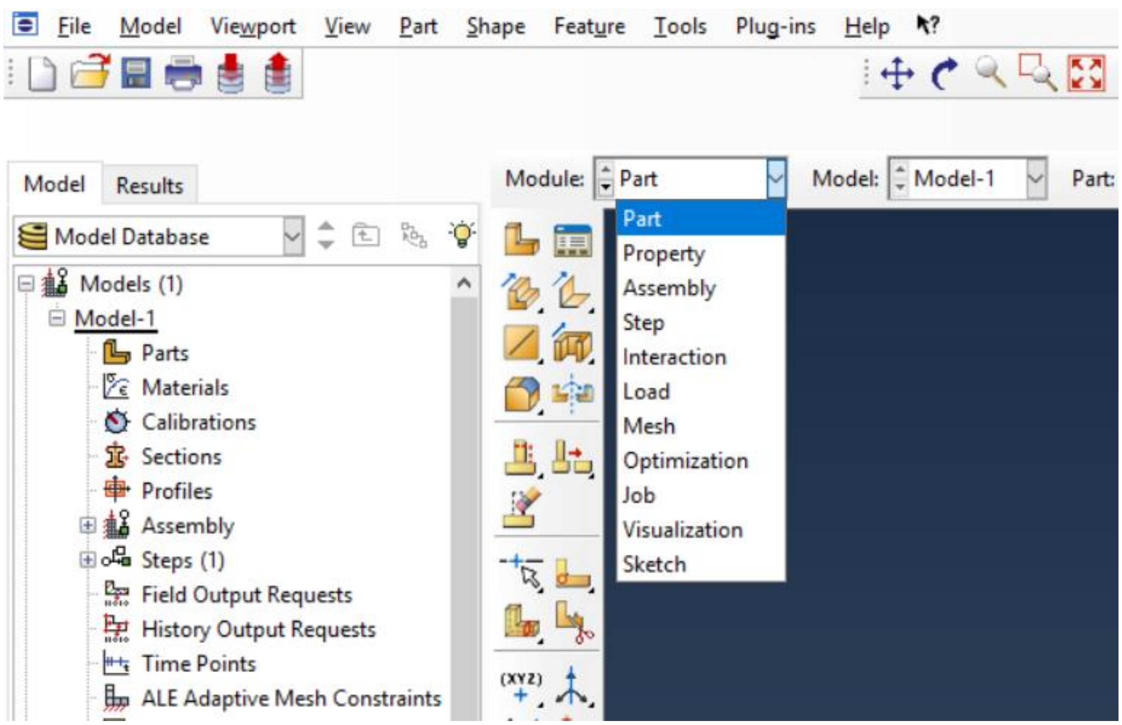
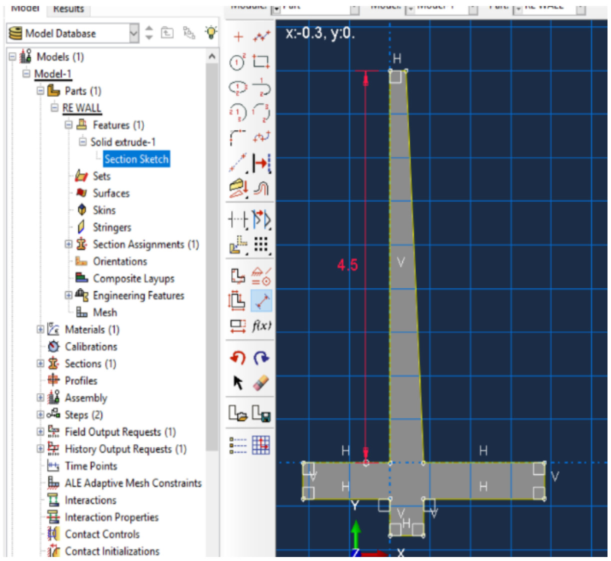


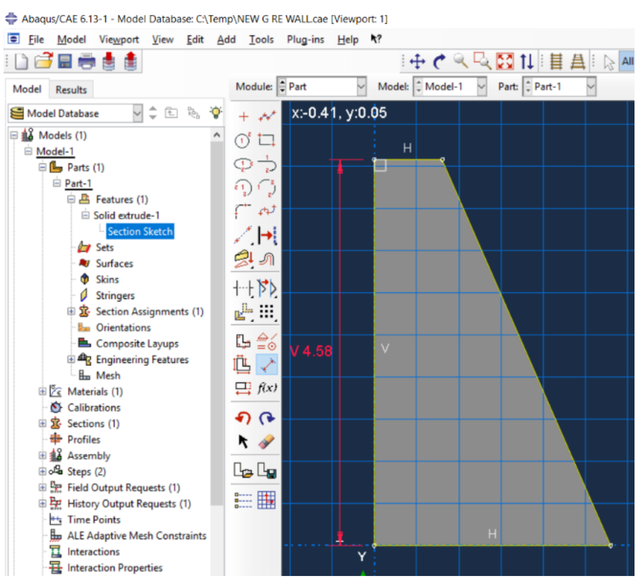
Fig 4.1: *Abaqus interface showing various steps*

4.2 Modelling work

This is the first step in the software analysis and geometry of all retaining walls are created in this step. Dimension values are obtained from numerical methods done in previous chapter and on that basis, geometries for all walls are created in the software. These are shown in figures given below.

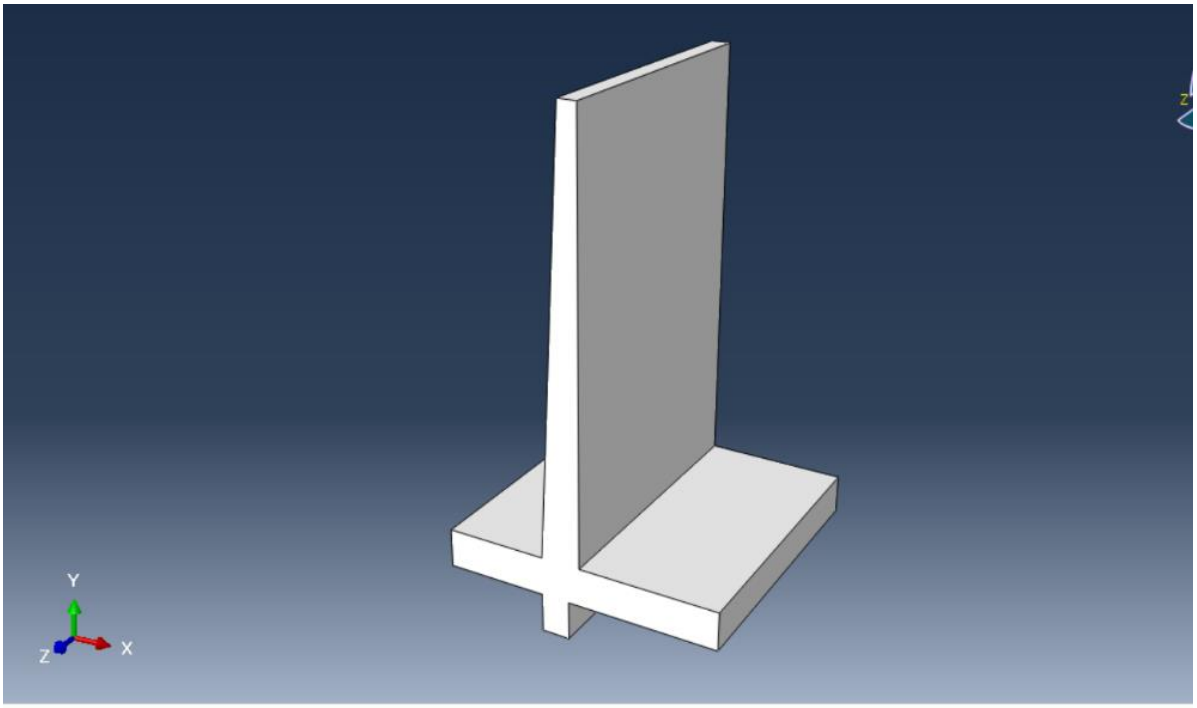


(a)

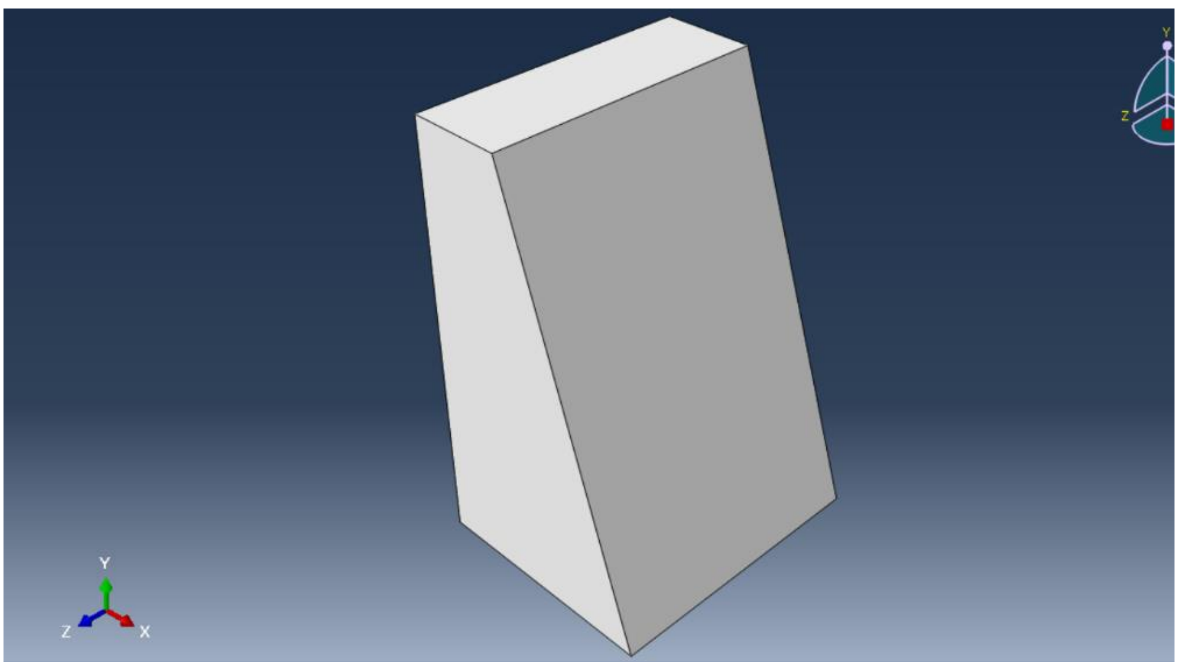


(b)

Fig 4.2 *Making of geometry for (a) cantilever wall (b) gravity wall*

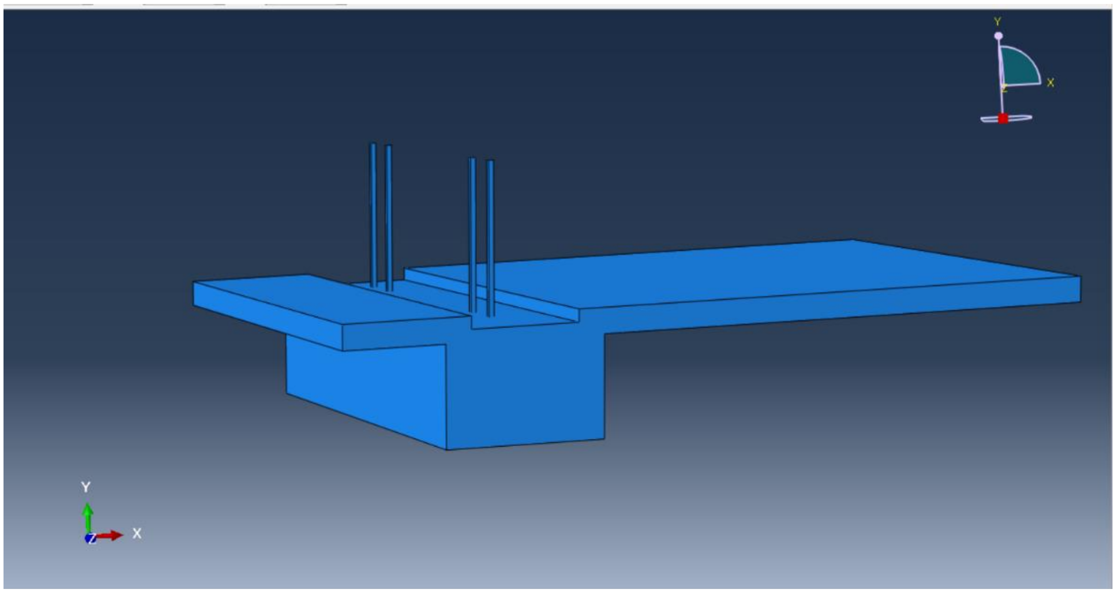


(a)

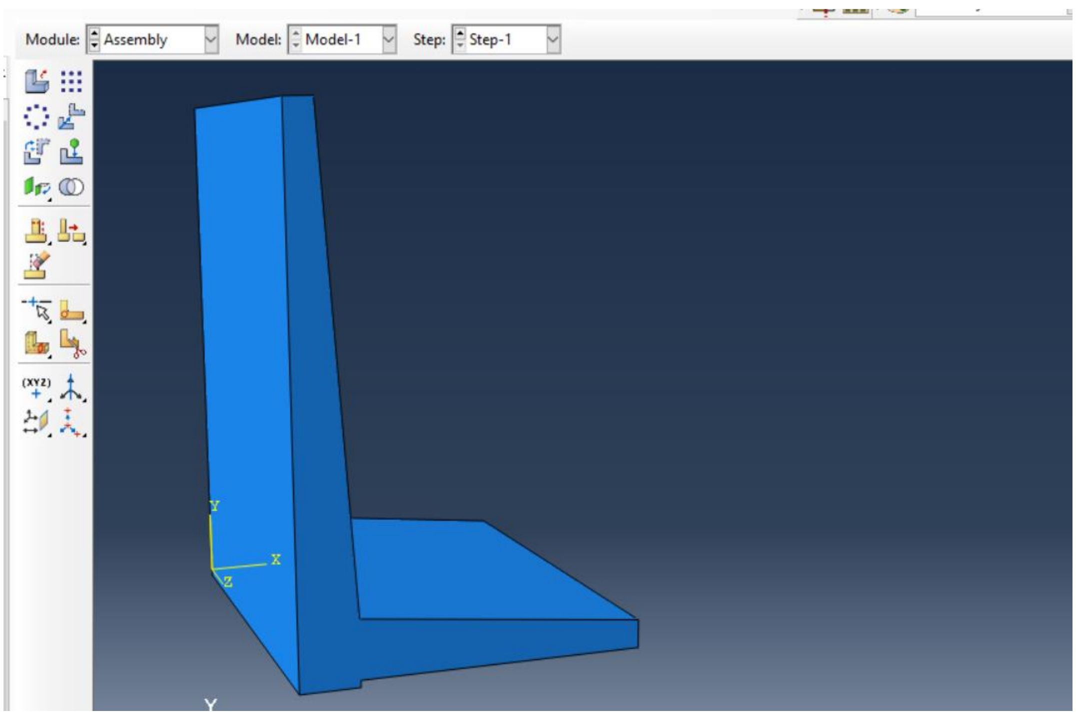


(b)

Fig 4.3 *Final model after providing thickness (a) for cantilever wall (b) for gravity wall*



(c)



(d)

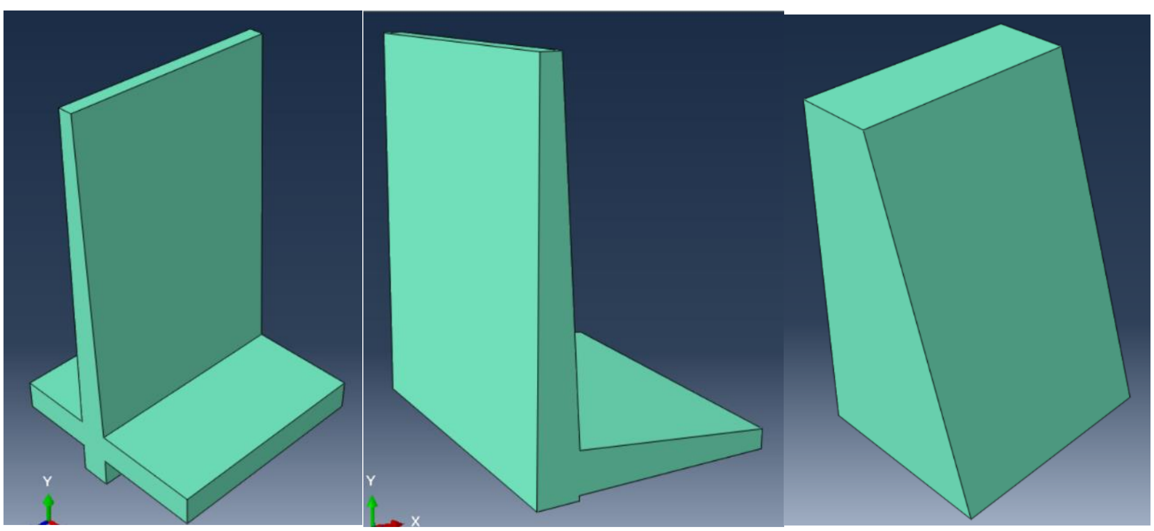
Fig 4.4 *Final model of precast retaining wall (c) levelling pad with anchor bars embedded (d) precast wall panel*

4.3 Material properties assignment

In this project following material properties are used for the analysis. Three type of materials are used for the construction of these retaining walls. These are shown in table 3.5.

Table 4.1 *Various material properties for the analysis*

Sr no.	Properties	Symbols	Steel	Concrete	Dry stone masonry
1	Young modulus	(E_C)	20000 N/mm^2	25000N/mm^2	14270 N/mm^2
2	Ultimate compressive strength	(f_C)	415Mpa	25Mpa	49.3Mpa
3	Density	(ϒ)	7850kg/m^3	2400kg/m^3	2400kg/m^3
4	Poisson ratio		0.3	0.2	0.2

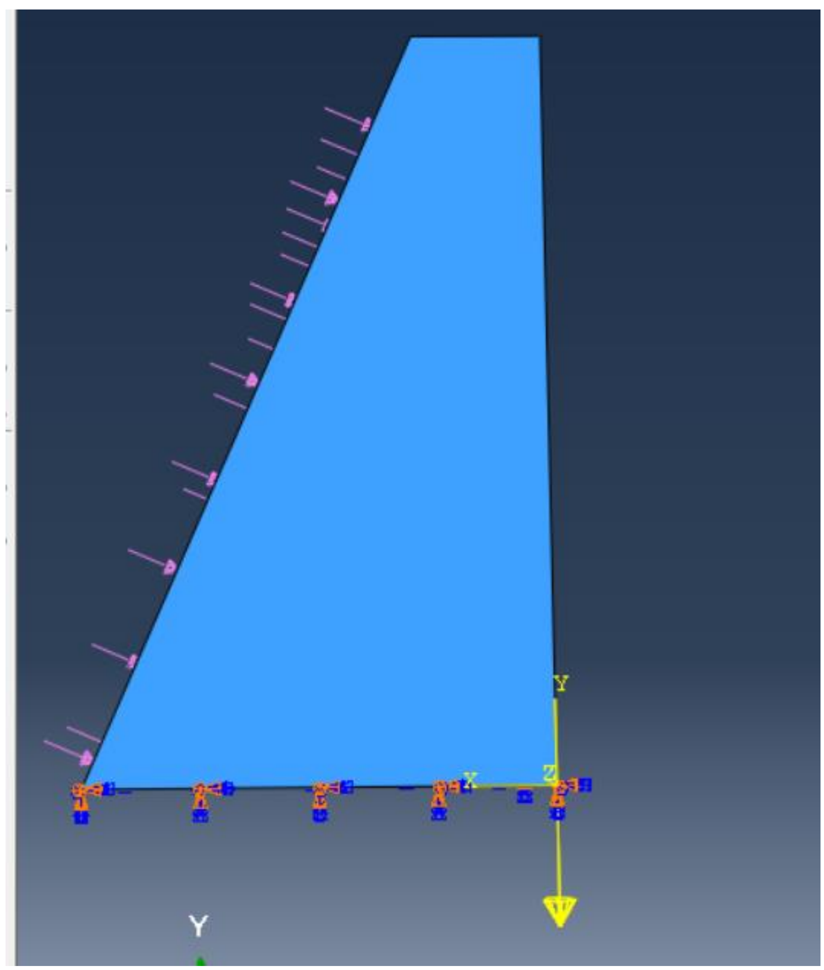


(a) *(b)* *(c)*

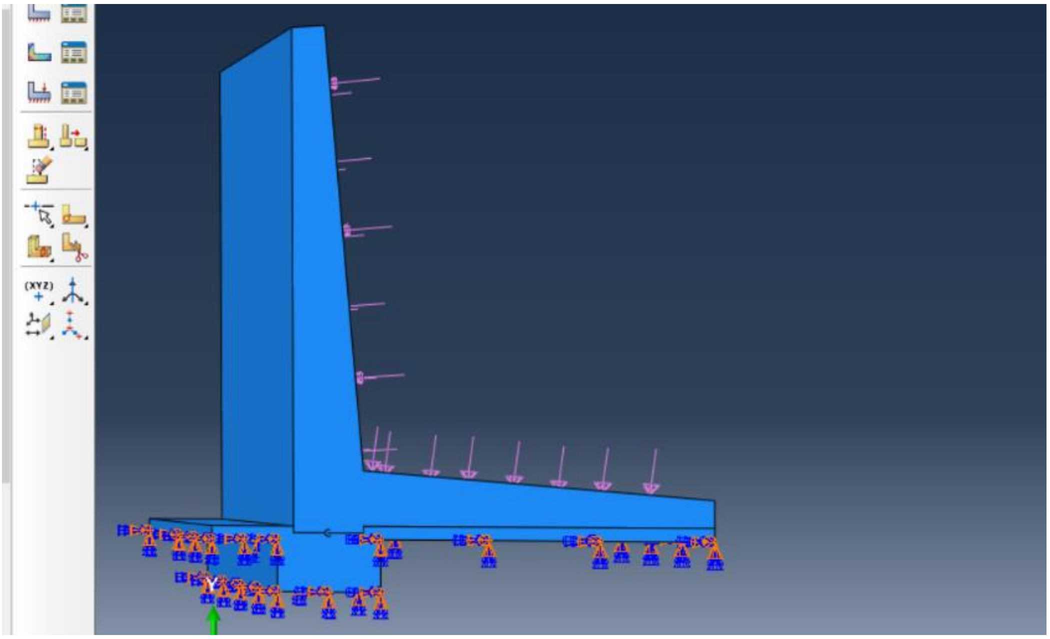
Fig 4.5 *Assigning material properties (a) to cantilever wall (b) to precast wall (c) to gravity wall*

4.4 Load and boundary conditions assignment

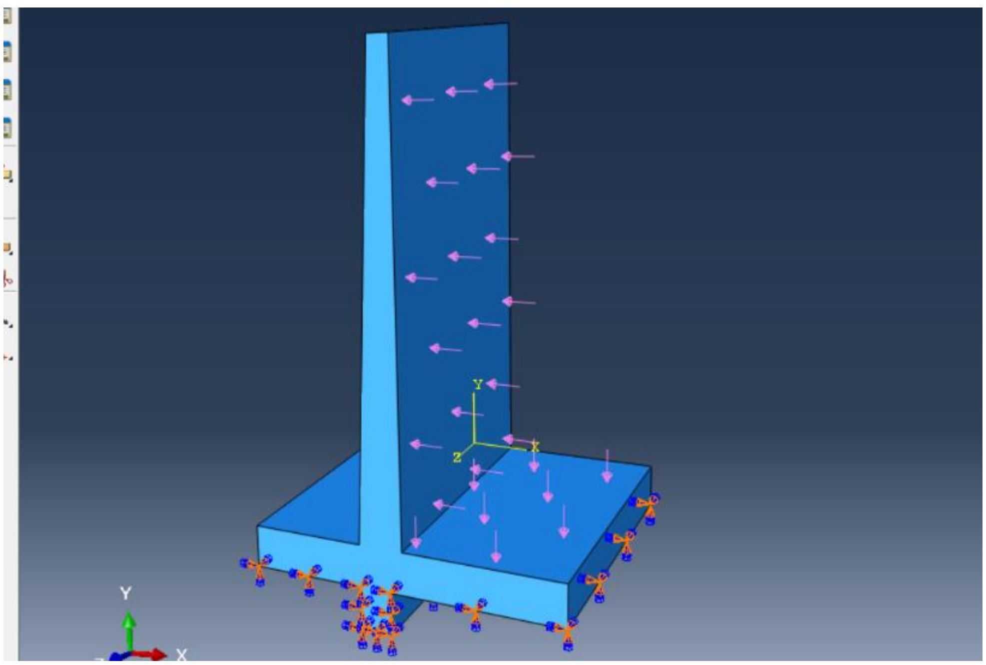
After creating the geometry and assigning material properties next step is to apply various service loads and boundary conditions. In this case pressure acting on the walls are already calculated. So we apply the loads directly on the models..In case of precast retaining wall and cantilever retaining wall earth pressure of 95kN/m^2,self weight and backfill load acting on the heel slabs are considered for analysis.In gravity retaining wall only gravity load along with earth pressure of 95 kN/m^{2}acting on the backfill side is applied. For the boundary condtion, ENCASTRE option is used. In this case the bottom surface is completely fixed and isnot allowed to translate or rotate in any direction. It is shown in figures given below.



(a)



(b)

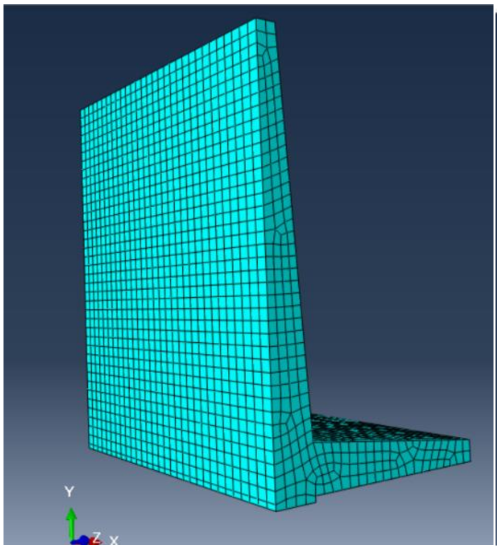


(c)

Fig 4.6 *Assigning loads and boundary condition to (a) gravity retaining wall (b) precast retaining wall (c) cantilever retaining wall*

4.5 Meshing of models

After assigning the loads and boundary conditons next step is to meshing the models. For all the models generated meshing size of 0.1 is taken and for the anchor bars 0.05.



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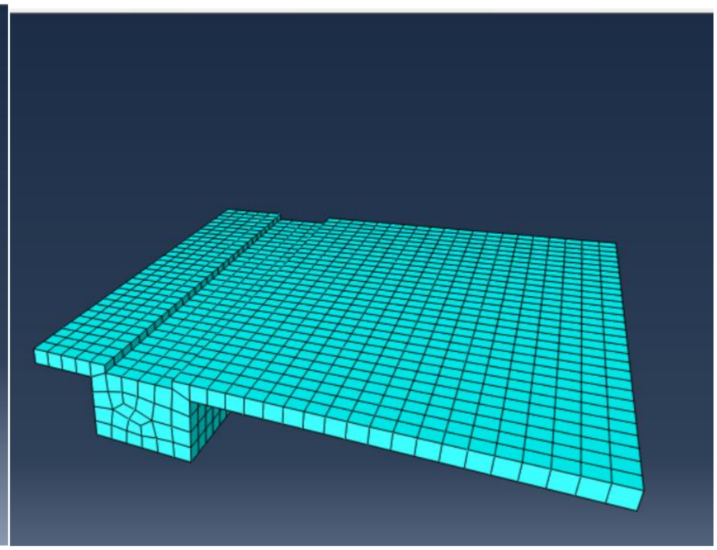

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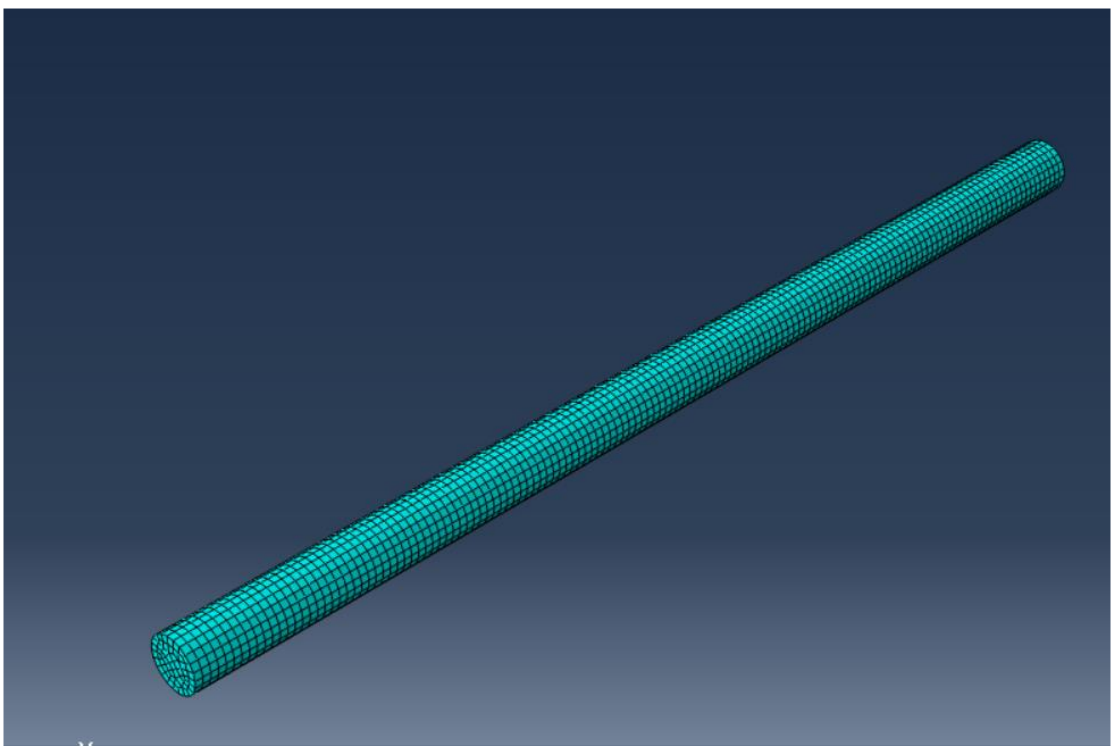
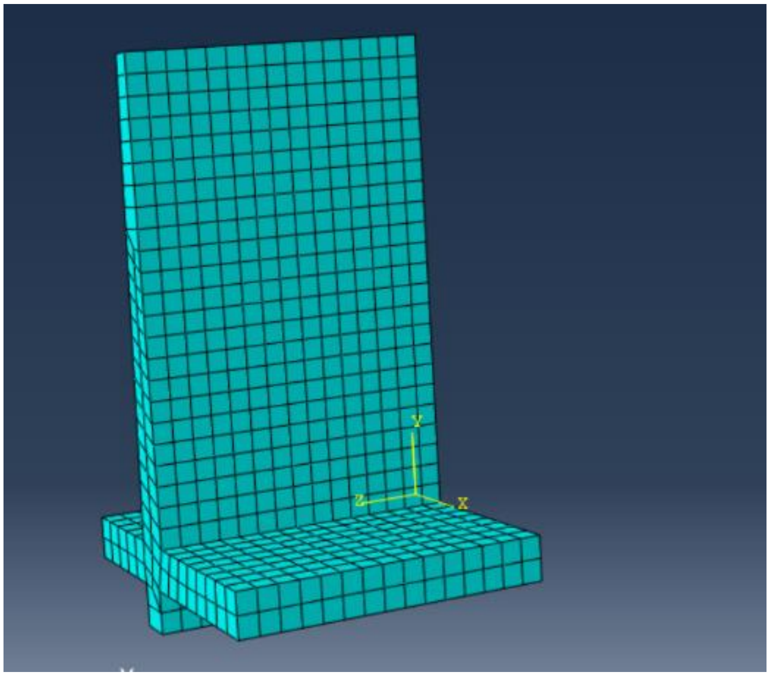
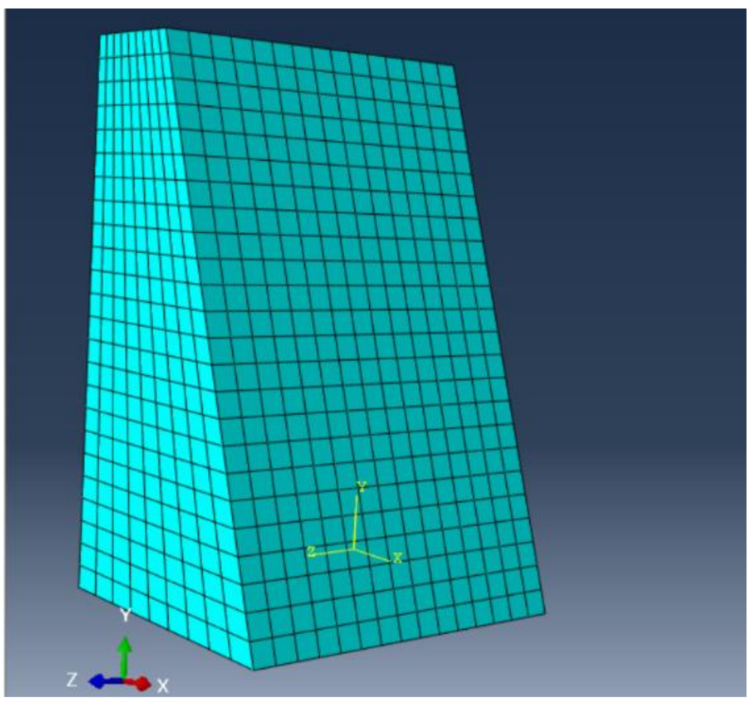


(c)



(d)



(e)

Fig 4.7 *Meshing of (a) precast wall panel (b) Levelling pad (c) Anchor bars (d) Cantilever retaining wall (e) Gravity retaining wall*

4.6 Analysis of model

Now all the steps are completed and model with all service loads and boundary conditions. Next step is to create JOB in the software where all the data and information is submitted and monitored and with no error in pre-processing, analysis get completed. After completion a visualization module helps to interpret the results.

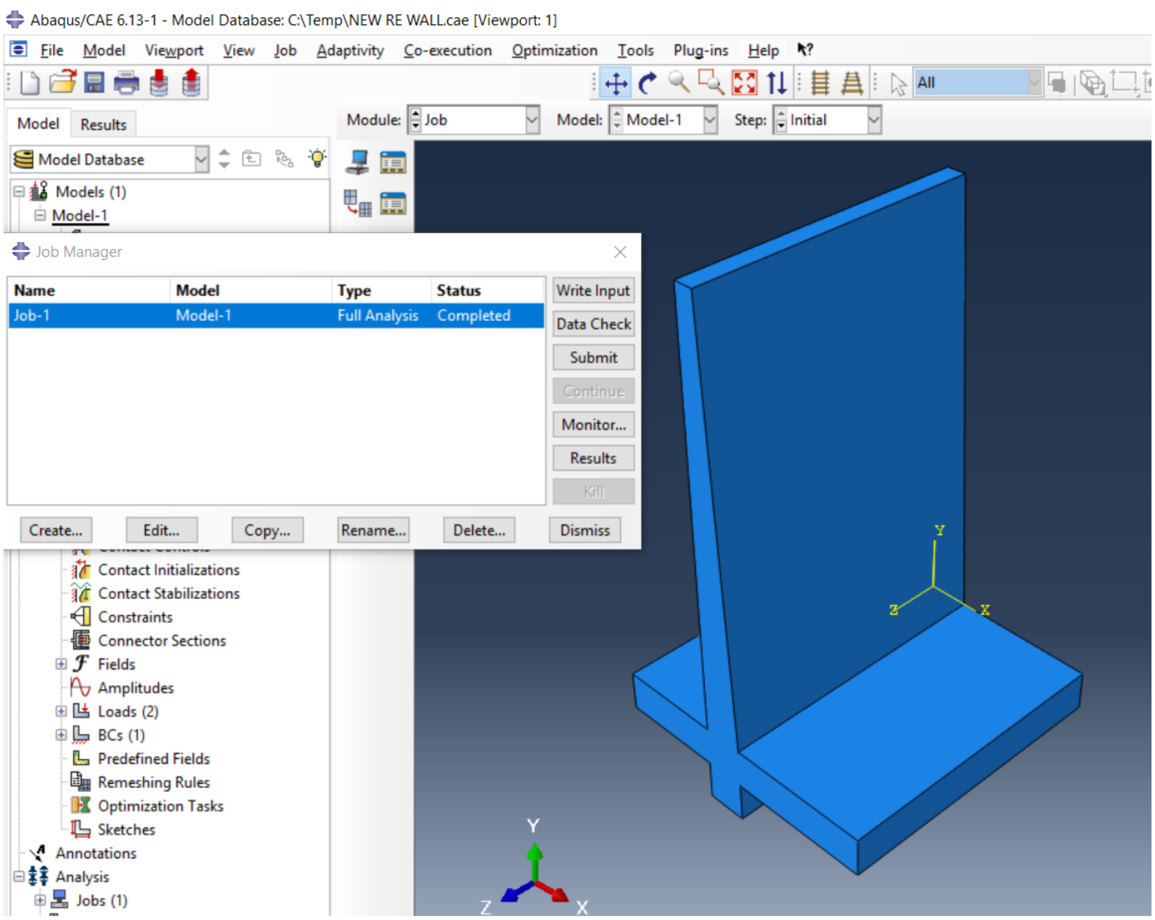


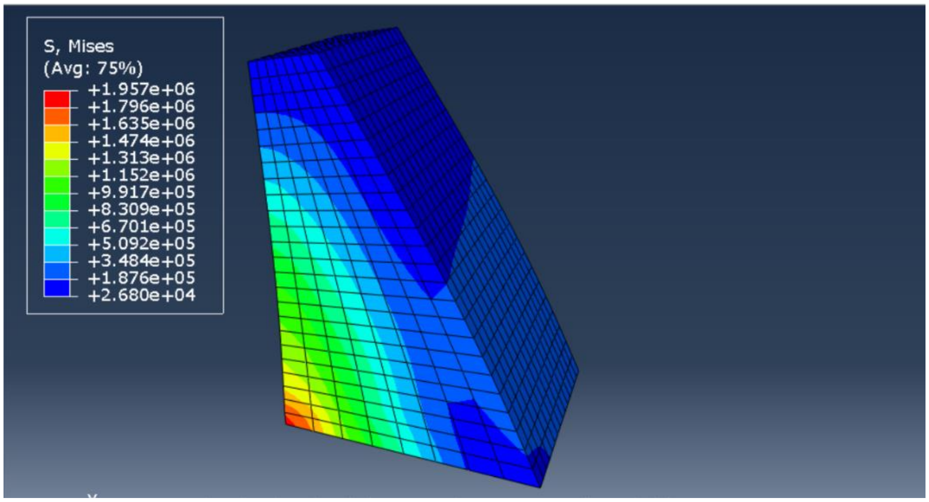
Fig 4.8 *Final command for the analysis*

CHAPTER 5

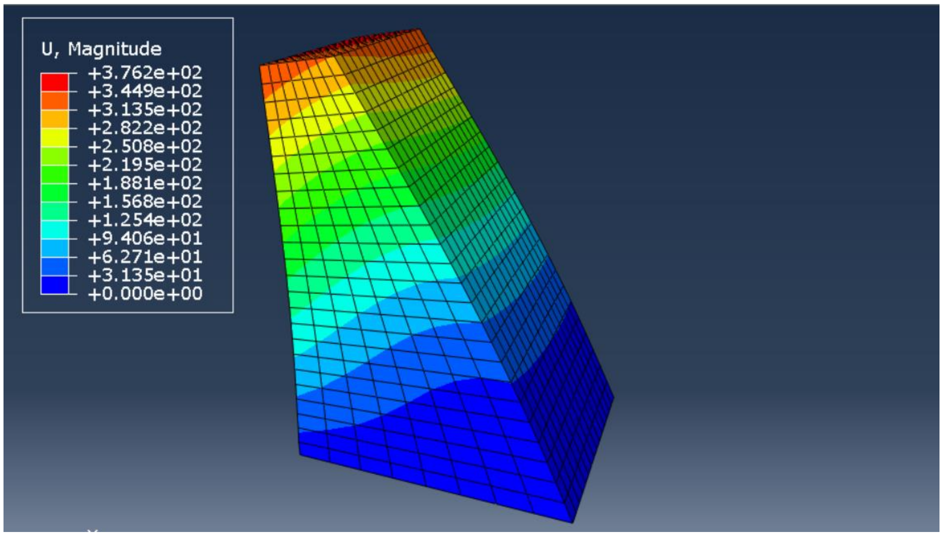
RESULTS AND DISCUSSION

5.1 SOFTWARE RESULTS

For gravity type retaining wall the stress distribution and deflection along the height of wall is shown in Fig 5.1.



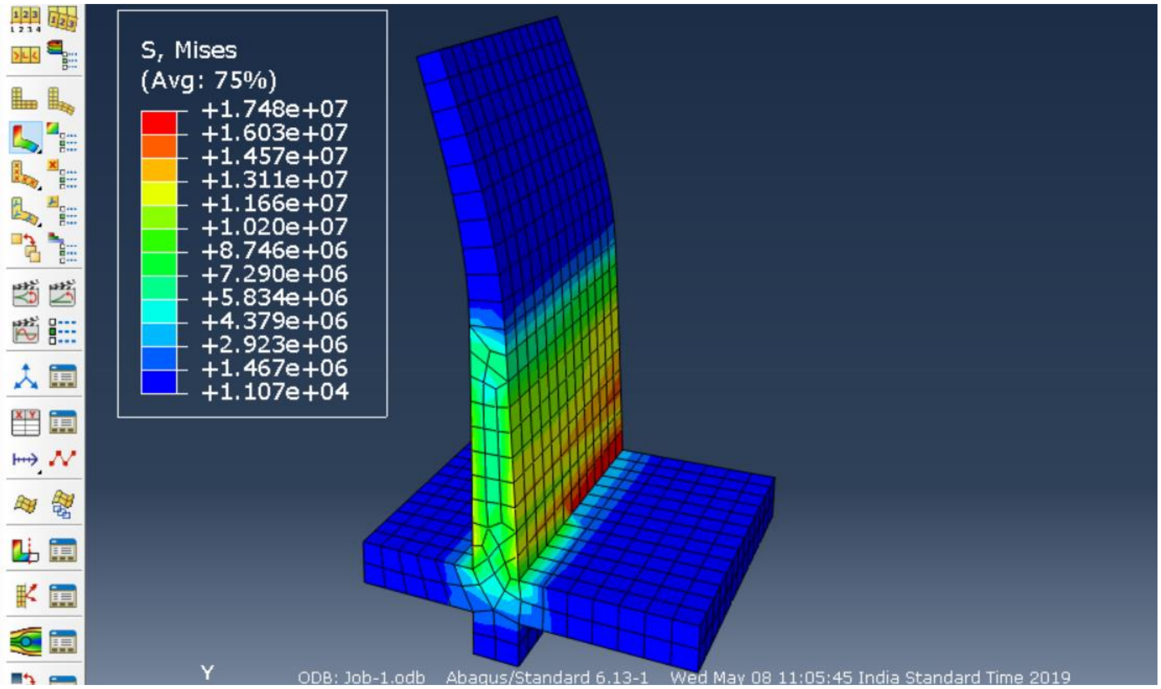
(a)



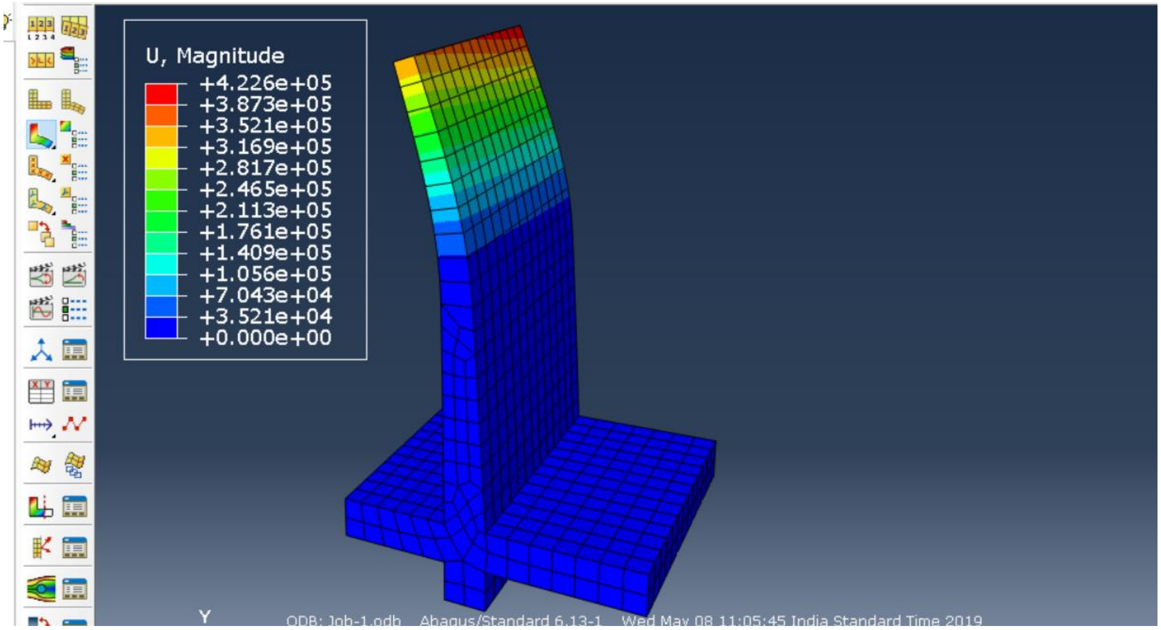
(b)

Fig 5.1 *For gravity retaining wall (a) stress distribution (b) deflection*

For cantilever type retaining wall the stress distribution and deflection along the height of wall is shown in Fig.5.2.



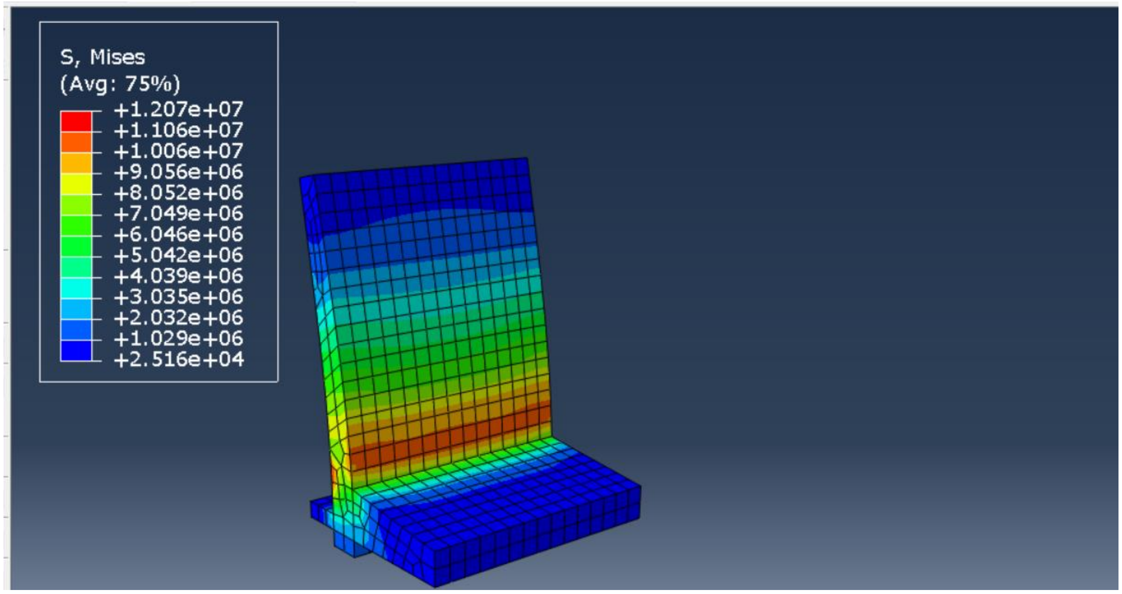
(a)



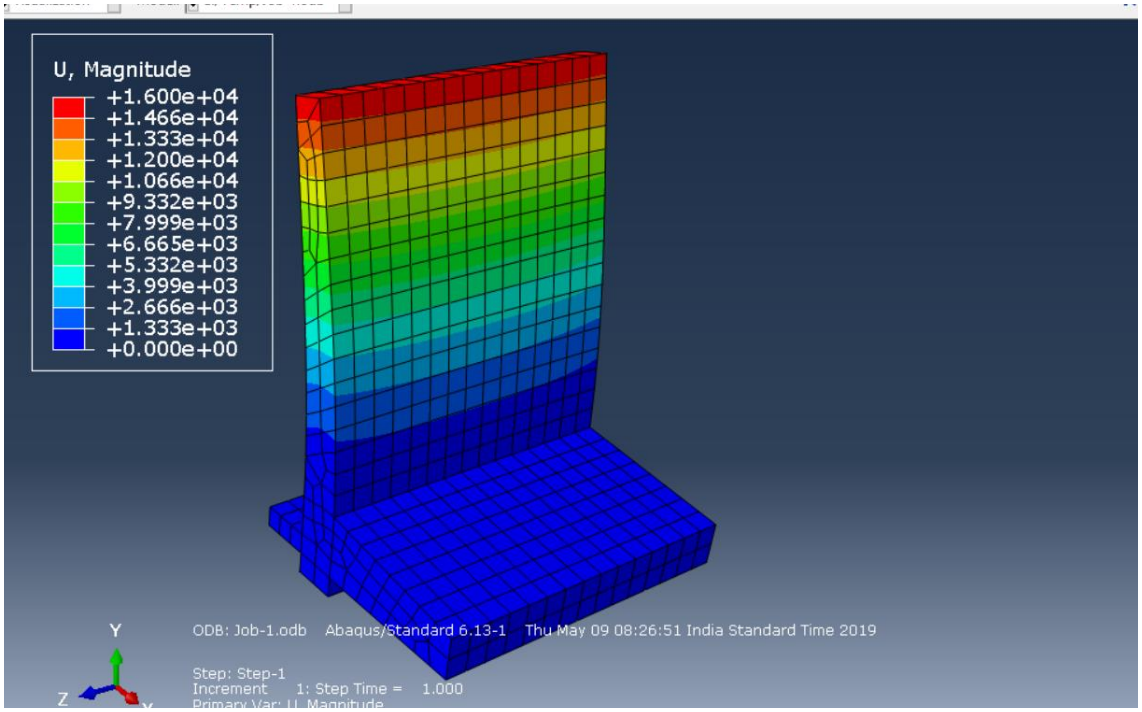
(b)

Fig 5.2 *For cantilever retaining wall (a) stress distribution (b) deflection*

For precast cantilever retaining wall the stress distribution and deflection along the height of wall is shown in Fig.5.3.



(a)

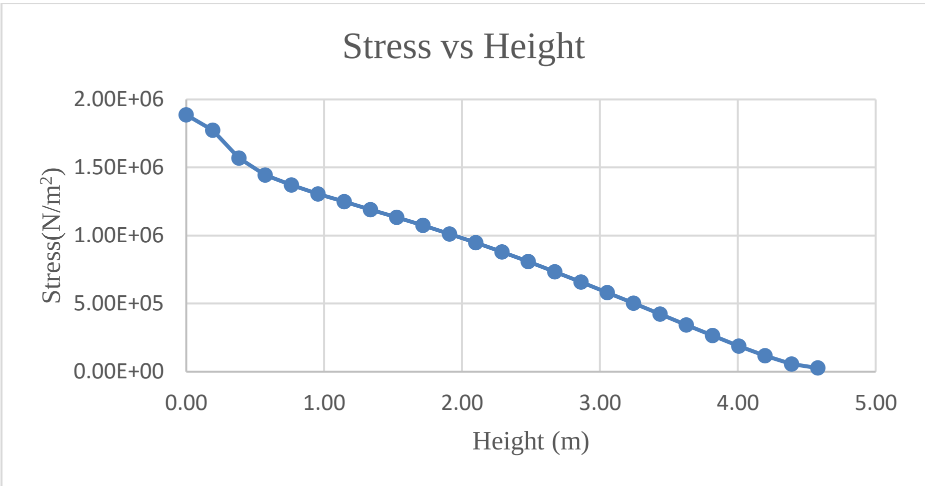


(b)

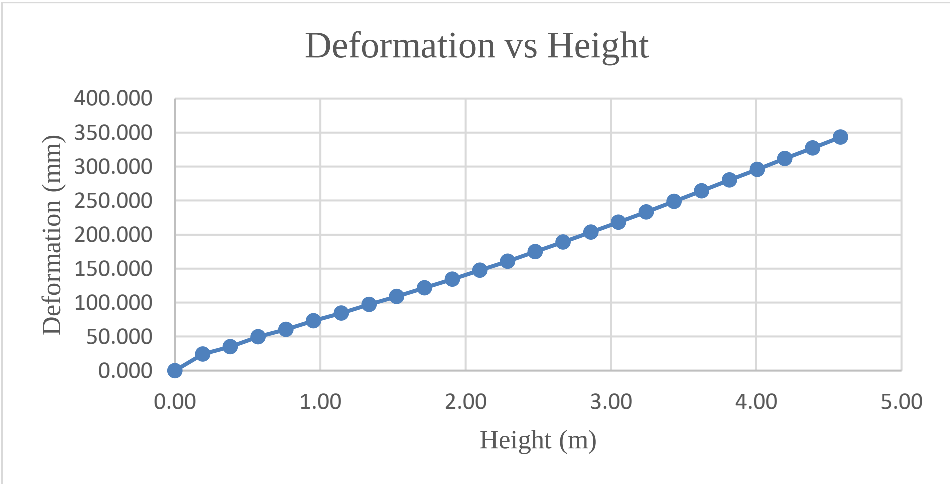
Fig 5.3 *For cantilever retaining wall (a) stress distribution (b) deflection*

5.2 GRAPHS AND DISCUSSION

Fig 5.4 (a) representing the graph between stress distribution along the height of the wall. From the graph we can conclude that stress magnitude is maximum at the bottom of the wall and goes on decreasing along the height. at top the value of stress reaches to almost zero. Fig.5.4(b) shows deflection graphs whose pattern is opposite to the stress distribution graph. Here at the bottom deflection value is minimum and reaches to maximum value when we move to the top of the wall. It means at top all these walls are facing the maximum deflection. The same patterns are followed by all the walls which are analysed in this project. They are shown in figures given below.



(a)



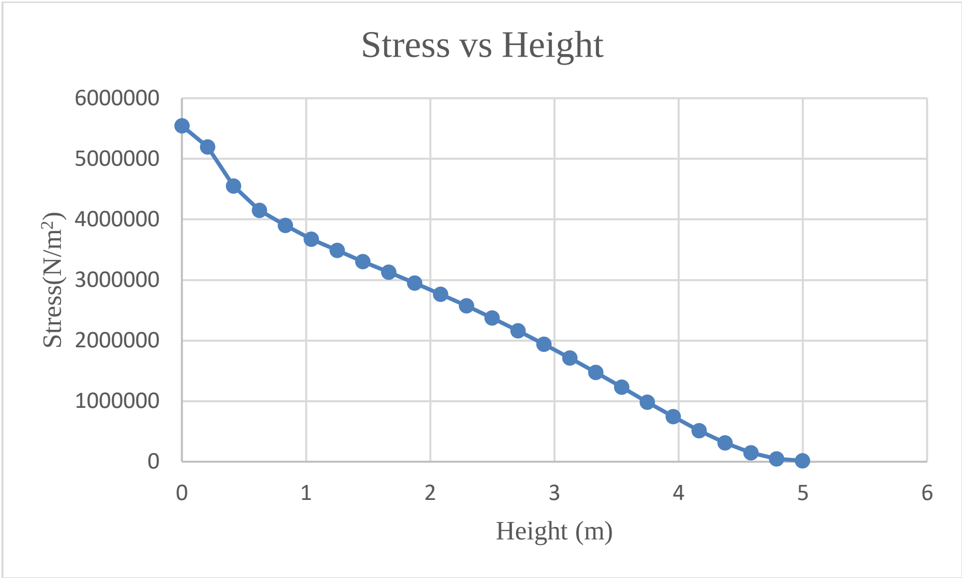
(b)

Fig 5.4 *Graphs for gravity retaining wall*

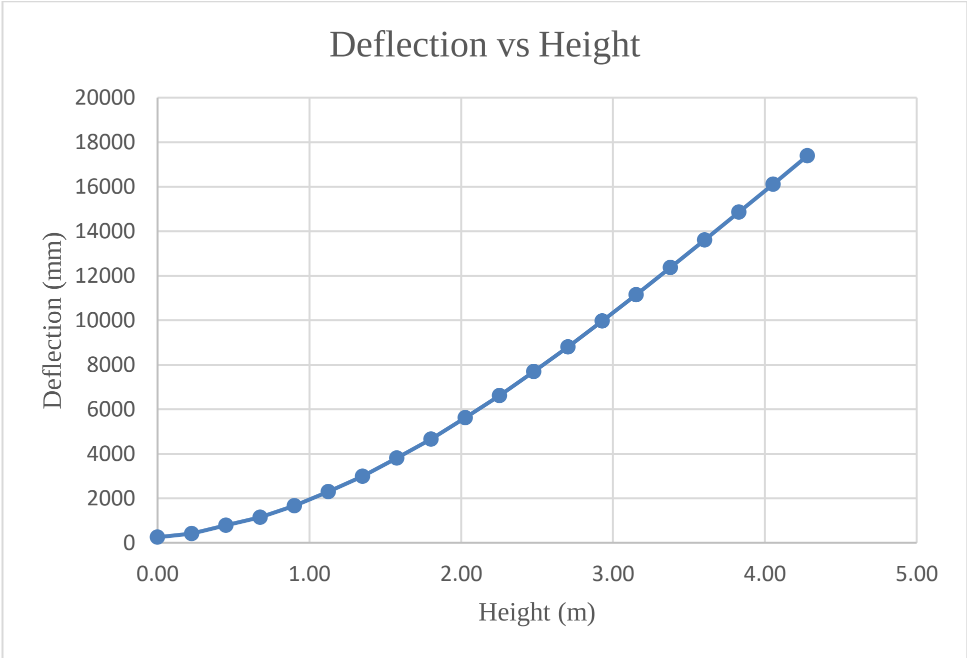
(a) stress distribution (b) deformation along the height

Table 5.1 *Variation of stress distribution and deformation in gravity type retaining wall*

For Gravity retaining wall		
Height (m)	**Stress (N/m^2)**	**Deformation (mm)**
0.00	3.73E+07	0.00E+00
0.21	3.64E+07	4.16E+02
0.42	3.51E+07	7.30E+02
0.62	3.49E+07	1.06E+03
0.83	3.50E+07	1.41E+03
1.04	3.51E+07	1.77E+03
1.25	3.49E+07	2.15E+03
1.46	3.43E+07	2.57E+03
1.67	3.35E+07	3.02E+03
1.87	3.23E+07	3.51E+03
2.08	3.08E+07	4.03E+03
2.29	2.91E+07	4.61E+03
2.50	2.72E+07	5.21E+03
2.71	2.52E+07	5.87E+03
2.92	2.30E+07	6.56E+03
3.12	2.07E+07	7.31E+03
3.33	1.84E+07	8.08E+03
3.54	1.59E+07	8.90E+03
3.75	1.35E+07	9.74E+03
3.96	1.10E+07	1.06E+04
4.16	8.68E+06	1.15E+04
4.37	6.47E+06	1.24E+04
4.58	4.69E+06	1.34E+04
4.79	3.34E+06	1.43E+04
5.00	2.71E+06	1.52E+04



(a)

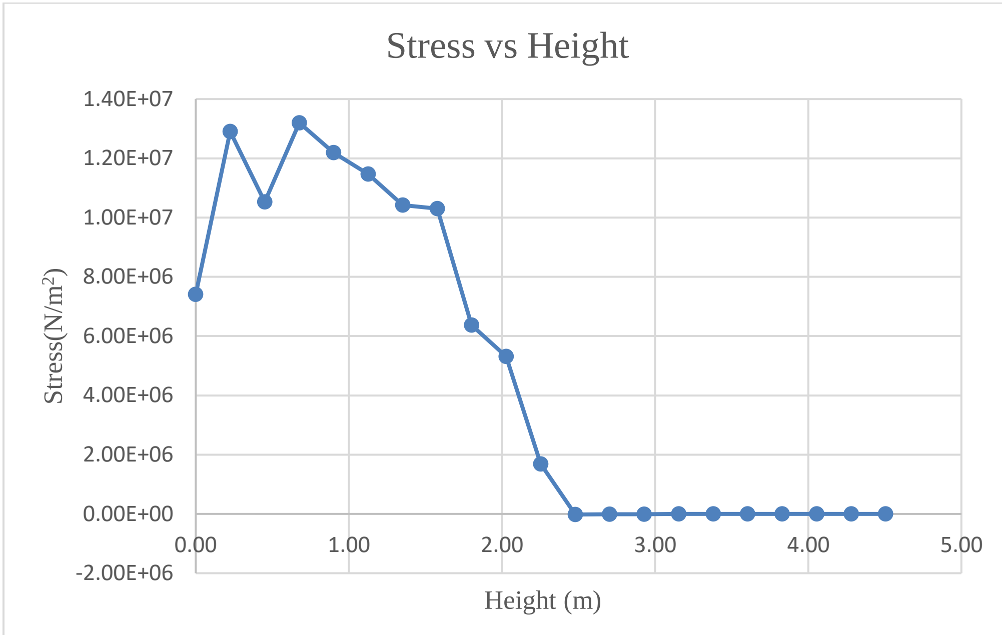


(b)

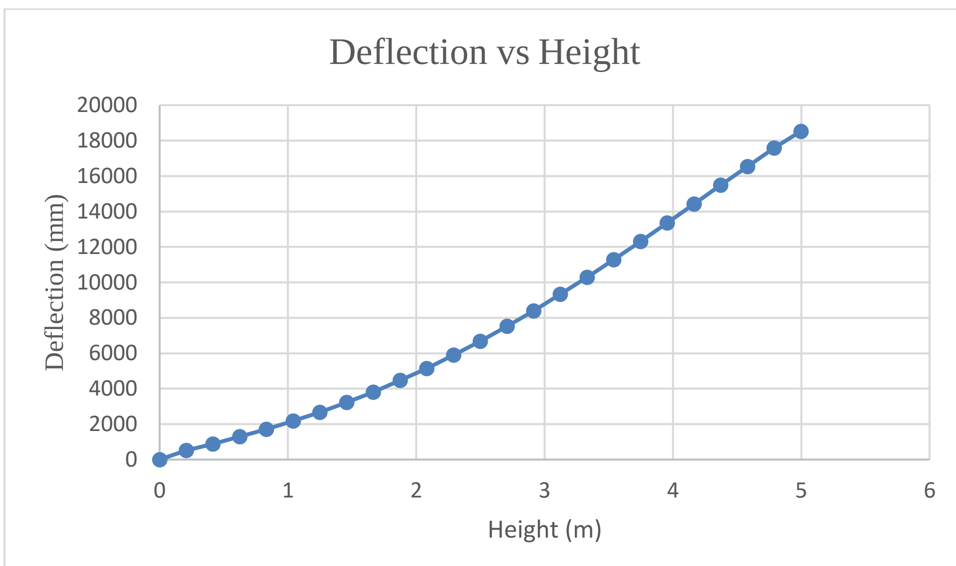
Fig 5.5 *Graph for cantilever retaining wall*
(b) stress distribution (b) deformation along the height of wall

Table 5.2 *Results for stress distribution and deformation*

For cantilever retaining wall		
Height (m)	**Stress (N/m^2)**	**Deformation (mm)**
0.00	7.40E+06	248.553
0.23	1.29E+07	411.92
0.45	1.05E+07	786.524
0.68	1.32E+07	1141.23
0.90	1.22E+07	1665.68
1.13	1.15E+07	2301.46
1.35	1.04E+07	2992.28
1.58	1.03E+07	3801.61
1.80	6.37E+06	4657.83
2.03	5.31E+06	5613.67
2.25	1.69E+06	6612.31
2.48	-1.97E+04	7687.83
2.70	-8.53E+03	8796.85
2.93	-5.83E+03	9962.76
3.15	-4.14E+03	11149.5
3.38	-3.33E+03	12374.9
3.60	-2.80E+03	13606.9
3.83	-2.45E+03	14862.5
4.05	-2.15E+03	16112.9
4.28	-2.05E+03	17386.1
4.51	-2.11E+03	17515.5



(a)



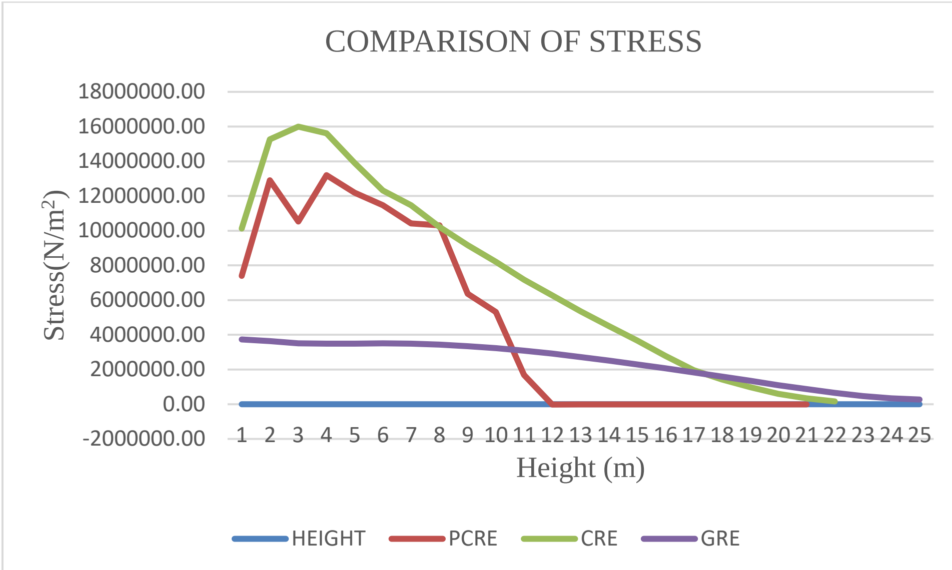
(b)

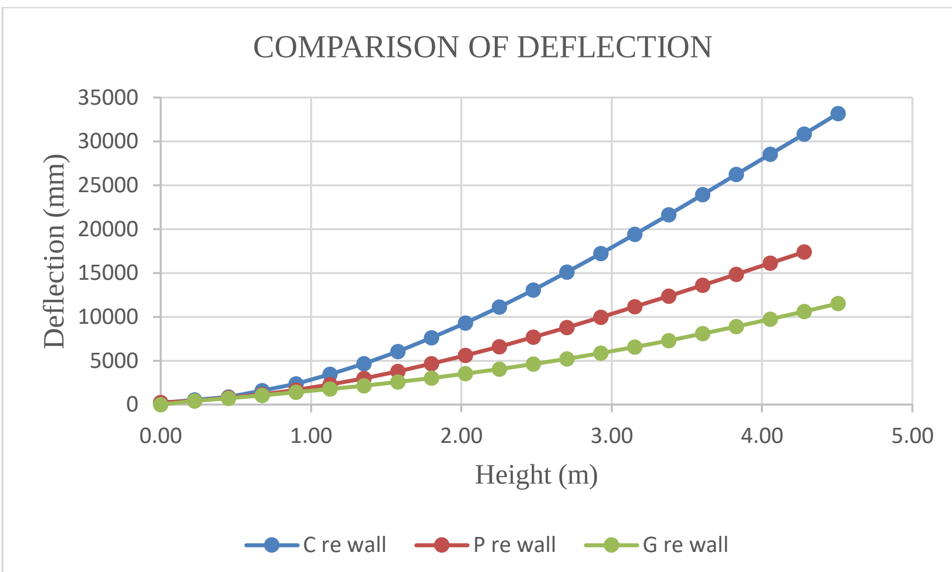
Fig 5.6 *For precast cantilever retaining wall*

(a) stress distribution graph (b) graph for deformation along the height of wall

Table 5. *Variation for stress distribution and deformation*

For Precast retaining wall		
Height (m)	**Stress (N/m^2)**	**Deformation (mm)**
0.00	1.01E+07	1.74E+02
0.20	1.53E+07	5.20E+02
0.40	1.60E+07	8.67E+02
0.59	1.56E+07	1.61E+03
0.79	1.39E+07	2.38E+03
0.99	1.23E+07	3.45E+03
1.19	1.15E+07	4.67E+03
1.39	1.02E+07	6.05E+03
1.59	9.17E+06	7.62E+03
1.78	8.20E+06	9.30E+03
1.98	7.18E+06	1.11E+04
2.18	6.27E+06	1.31E+04
2.38	5.35E+06	1.51E+04
2.58	4.50E+06	1.72E+04
2.77	3.68E+06	1.94E+04
2.97	2.80E+06	2.16E+04
3.17	1.96E+06	2.39E+04
3.37	1.43E+06	2.62E+04
3.57	983019	2.85E+04
3.77	594540	3.08E+04
3.96	344169	3.32E+04
4.16	161835	3.55E+04





(b)

Fig 5.7 *Graphs for comparison of*

(a) stress distribution (b) deformation along the height of wall

Here,

CRE is cantilever retaining wall, PCRE is precast retaining wall and GRE is gravity retaining wall.

Fig 5.7 (a) and (b) represents the comparison of stress distribution and deflection respectively of all the walls which are analysed in this project. Stress distribution and deflection in gravity retaining wall is least among three but due to its bulky nature, large amount of raw material manpower and money is required therefore, it is totally uneconomical approach to use this wall for large heights and earth pressure values. But when comparison is done between cantilever and precast retaining wall, we see deflection in cantilever wall is much more than precast wall and value of stresses are minimum also. In terms of their casting time, precast walls are much faster to fabricate and install.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

In this project I made an overall analysis on the stability of the conventional and precast retaining walls designed for same parameters and for same service loads. From my analysis, I concluded the following results which are mentioned below.

1. The overall stability of the precast retaining wall is much better to the conventional retaining walls as shown in Fig 5.7. There is a decrease of almost 21% in the stress values at the bottom of stem and 35% to 40% reduction in deflections.
2. Stem thickness reduced by 12% at bottom and overall reduction in total volume of precast wall by 9% makes this more economical.
3. The estimated construction period of this wall system is 2 to 3 hours with least requirement of manpower.

6.2 FUTURE SCOPE

Precast retaining wall is the best and cheap alternative to conventional retaining walls. The main advantages of this system are enhanced durability compared to cast in-situ, fast rate of construction and less use of resources like manpower, raw materials and money. In today's era also, there are various precast retaining wall systems that are used by people around the world but still it has not become a large-scale product due to unavailability of related scientific data and methods. For further research there is enough scope in this sector which is mentioned below.

1. Research can be done on the methods to increase the bending moment resistant capacity of L shaped precast retaining wall.
2. Use of prestressing methods in the precast wall panels to improve their strength and overall performance can also be done.
3. Use of lightweight materials can also be involved in the casting of precast wall panels.
4. New methods to fix the stem and heel slab can also be explored.

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