IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 16, Issue 4 Ser. II (Jul. - Aug. 2019), PP 01-07
www.iosrjournals.org

Optimization of Cantilever Retaining Wall Using Genetic Algorithm Method

R. J. Fernandes[1], Mithun K Mhalsekar[2]
[1, 2]*(Department Civil Engineering, SDM College of Engineering and Technology, Dharwad, India,)*
Corresponding Author: Mithun K Mhalsekar

***Abstract**: Cantilever retaining wall is widely used in civil engineering, for retaining a back fill soil. Now a day it is easy to get safe design due to recent advances in design field but safety with economy is the basic need of present generation, hence it is necessary to go for optimum design. Cantilever Retaining wall height is optimized for minimum 4mts and maximum 7mts. Design of the cantilever retaining wall has been design to with stand the various forces acting on it. The cantilever retaining wall is designed by limit state method. A computer programme is written in MATLAB for optimization process using genetic algorithm method. Parametric study has been carried out for different grades of concrete and different heights of retaining wall.*

***Key words:**Optimization, MATLAB, Genetic algorithm, Retaining wall.*

Date of Submission: 08-07-2019 Date of acceptance: 23-07-2019

I. Introduction

Process of finding most economic and best results, with maximum benefit at minimum cost or quantity is called optimization. Due to recent development in structural designing field it has become easy to get a safe design but it is difficult to find the economical design, hence optimization technique is necessary to get most economical design. In this project the cost optimization of cantilever retaining wall is carried out by using genetic algorithm.

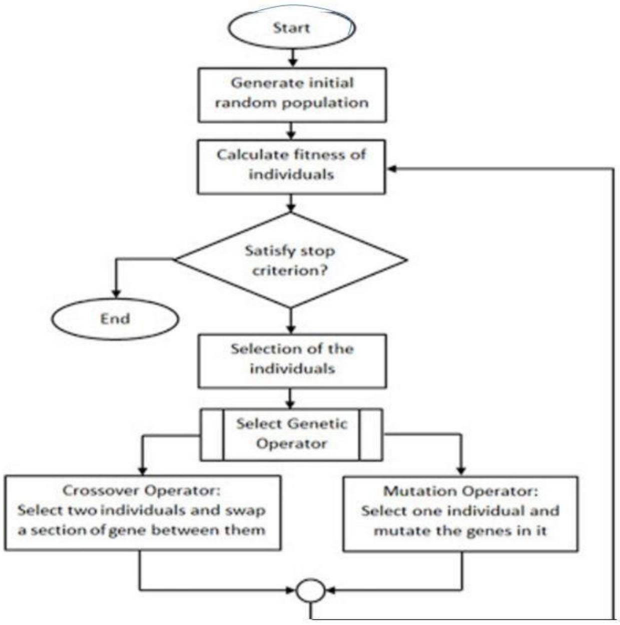
II. Optimization method

Genetic algorithm method is used as a tool in artificial intelligence and computer programming. Search is based on Darwin's theory of survival of fittest. It is non-traditional search technique in most of cases it is used to find the most economical global optimum solutions. This technique starts with a set of design points with available variables; it works on the principal of natural genetic and natural selection. From the early set of design points, new set of design points are generated and weaker points are removed.

The genetic algorithm differs from other methods in several aspects

I. Genetic algorithm works with a coding of the set of feasible point rather than the set generated itself.
II. It finds from a random set of points rather than the set itself.
III. Derivatives of the objective function are not used.
IV. It uses random operation in each iteration process.

The flow chart of genetic algorithm illustrates the working process



III. Methodology

1) Study the guidelines for the design of cantilever retaining wall by using IS 456:2000 code.

A) General forces acting on the retaining wall.

The variousforces acting on the retaining wall structure are consistent; formulation includesactive and passive forces on the front of the toe and baseshear key sections and the bearing force of the basesoil.
Wc= combined weight of all thesections of the R.C.C wall.
WS =weight of backfill acting on the heel.
Wt = weightof soil on the toe.
Q = surcharge load.
Pa= forcedue to the active earth pressure.**Pk**and**Pt** =forces due to passive earth pressure on the base shearkey and front part of the toe section.
Pb =force due to the bearing stress of the base shear.

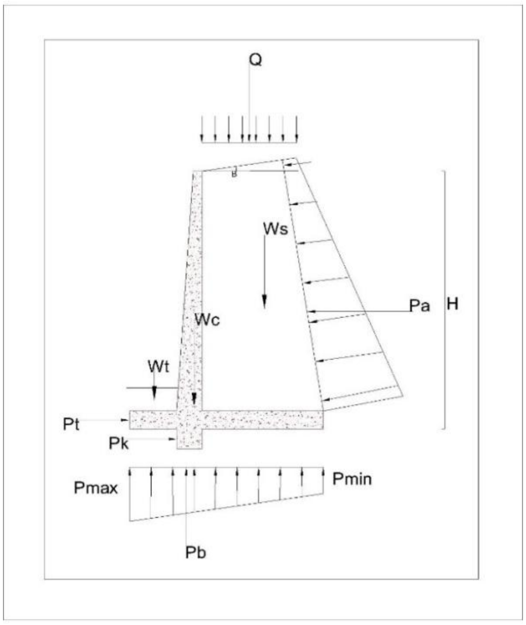


Fig 3.1 General forces acting on the retaining wall.

B) Design steps of retaining wall: The following analysis and design step has been followed for the writing of MAT LAB program.

1. Determination of depth of the foundation: The depth of the foundation depends upon the depth at which adequate bearing capacity is available at the site.

$$D_f = \frac{p_o}{\gamma}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$$

Where p_o is the safe bearing capacity of the soil at the safe at the site. γ is the density of the soil at the safe at the site. ϕ Angle of repose.

2. Height of the wall: The overall height of wall H is equal to height of the backfill at the face of wall plus the depth the foundation.

3. Base width: The width B of the base normally varies from 0.45H to 0.70H, depending upon the characteristics of the backfill. It is derived from the equation given below,

$$B = 1.5\sqrt{\frac{2\,(p_a\,y_a + p_s\,y_s)}{\gamma\,H}}$$

$$H = over\ all\ height\ of\ the\ retaining\ wall.$$

p_a and p_s Total horizontal forces on the wall due to active earth pressure.
y_a and y_s are the heights of these forces from the base of the footing slab.

4. Stem height: The preliminary stem height is established from overall height of the wall H and the base thickness D as the thickness at the base is determined from the imposed shear and the moments.

5. Design of the base slab: The heel is subjected to upward soil pressure and downward gravity loads due to its self-weight and earth above it. The latter being larger causes a hogging moments. The steel placed at the top face. The toe is subjected to the net upward pressure and reinforcement is placed at the bottom of the slab.

6. Design of the stem: The stem is designed as a vertical cantilever subjected to a triangular or trapezoidal. Main reinforcement is provided on the back fill face of the stem. Secondary reinforcement may be curtailed at the top portion of the stem. Secondary reinforcement is provided @0.15% in mild steel and 0.12% in case of HYSD steel.

C) Stability requirement

1. Overturning: To ensure stability against overturning about the edge of the toe slab, stabilizing moments due to the gravity loads should be more than the overturning moments due to lateral force so as to get a factor so as to get factor of safety in the range of 1.5 to 2.0. according to IS:456 2000,

2.Sliding: The resisting force against sliding should be more than the sliding force so as get a factor of safety of 1.55

Factor of safety = $\frac{\mu \sum W}{p_{ah}}$

Where

$$\sum W = Total\ gravity\ load.$$
$$p_{ah} = Horizontal\ components\ of\ earth\ pressure.$$
$$\mu(=\tan\phi) = friction\ coefficient\ between\ base\ and\ ground.$$
$$\phi = angle\ of\ repose\ or\ angle\ of\ internal\ friction.$$

In case the factor of safety is less than 1.55, a base key may be provided to obtain additional resisting force to sliding. The base key develops a passive earth pressure of

$$P_p = \frac{1}{2}\,k_p\,\gamma\,h_1^2 a$$

where h_1 is the depth of the base key including the thickness of the toe slab.

3. Basepressure: The vertical pressure on the soil under the base should not exceed the bearing capacity of soil. There should be no tension under the base, since tension means that. The heel will be lifted above the soil, which is not permissible.

IV. Optimization of cantilever retaining wall

Optimizer is built on bases of genetic algorithm programming; the problem is automated by writing a program in MATLAB software which is user friendly and flexible for optimization of cantilever retaining wall. Few important features of the program are mentioned bellow.

•Analysis and designing of the retaining wall is coded in the MATLAB software.

•Each commands used in the code are clearly defined in the form of comment for self-explanatory of the program.

•The user has to enter variables, constraints and the number of individuals per subpopulations and maximal Number of generations and generation gap.

•The user has to enter permissible stresses and permissible deflection for the grade of concrete selected as per code.

Following are the inputs required for the optimizer:

i) No of variables. ii) No of constraints.

iii)Maximum number of generations. iv) Lower limit of variable.

v) Upper limit of variables.

A) Variables

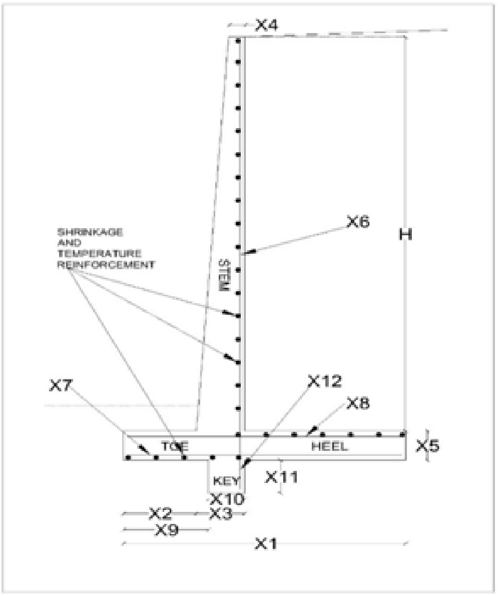


Fig 4.1 Variables diagram

Variables	Description
X_1	Width of the base.
X_2	Toe projection or toe slab.
X_3	Thickness at the bottom of the stem.
X_4	Thickness at the top of the stem.
X_5	Thickness of the base slab.
X_6	Vertical steel reinforcement in the stem.
X_7	Horizontal reinforcement in the toe.
X_8	Horizontal reinforcement in the heel.
X_9	Distance from toe to the thickness of the base shear key.
X_{10}	Width of the shear key.
X_{11}	Depth of the shear key.
X_{12}	Vertical reinforcement in the base shear key.

Table 4.1. Variables diagram

B) Lower and upper limits [3]

Table 4.2 Lower and Upper limits

Variables	Lower limits	Upper limits
X1=Width of the base.	0.4*h*(12/11)	(0.7*h)/0.9
X2=Toe slab.	[0.4*h*(12/11)]/3	[(0.7*h)/0.9]/3
X3=Thickness @ bottom of the stem.	0.2	(h/0.9)/10
X4=Thickness @ the top of the stem.	0.2	0.2
X5=Thickness of the base slab.	[h*(12/11)]/12	(h/0.9)/10
X6=Vertical reinforcement in the stem.	0.0012* X3	0.04*X3
X7=Horizontal reinforcement in the toe.	0.0012*X5	0.04*X5
X8=Horizontal reinforcement in the heel.	0.0012*X5	0.04*X5
X9=Distance from toe to the thickness of the base shear key.	0.4*h*(12/11)	(0.7*h)/0.9
X10=Width of the shear key.	0.3	(h/0.9)/10
X11=Depth of the shear key.	0.3	(h/0.9)/10
X12=Vertical reinforcement in the base shear	0.0012*X10	0.04*X3

C) Constrains

Table 4.3 Constrains

Inequality constraints	Failure mode	Equations
g1(X)	Overturning stability	$FOS - \left(\frac{Mvtotal}{Mhtotal}\right) \leq 0$
g2(X)	Maximum bearing capacity	$P\max - sbc \leq 0$
g3(X)	Minimum bearing capacity	$-P\min$
g4(X)	Sliding stability	$FSs - \left(\frac{Vtotal * \mu + hrz\ forces\ from\ passive\ pressure}{Htotal}\right) \leq 0$
g5(X)	No tension condition	$E - \left(\frac{B}{6}\right)$
g6(X)	Moment at bottom of stem	$Ms - Mrs \leq 0$
g7(X)	Moment at toe	$Mt - Mrt \leq 0$
g8(X)	Moment at heel	$Mh - Mrh \leq 0$
g9(X)	Moment at shear key	$Mk - Mrk \leq 0$
g10(X)	Shear at bottom of stem	$Vs - Vus \leq 0$
g11(X)	Shear at Toe	$Vt - Vut \leq 0$
g12(X)	Shear at heel	(0.12/100)*b*D .At
g13(X)	shear key	$Vk - Vuk \leq 0$
g14(X)	Minimum area reinforcement	(0.12/100)*b*D –As ≤ 0
g15(X)		(0.12/100)*b*Ds–At ≤ 0
g16(X)		(0.12/100)*b*Ds–Ah ≤ 0
g17(X)	Maximum area reinforcement	Ass – (4/100)*b*Ds ≤ 0
g18(X)		Ast – (4/100)*b*Dt ≤ 0
g19(X)		Ash – (4/100)*b*Dh ≤ 0
g16(X)	Additional geometric constraints	f (cost) = Cs*Wst + Cc*Vc

Nomenclature:

Mhtotal = Total horizontal moment of forces that tends to overturn about toe.
Mvtotal = Total vertical moment of forces that tends to resist overturning about toe.

FSo = Factor of safety against overturning.

Pmax=Maximum contact pressure at the interface between the wall structure and the foundation Soil.

Pmin = Minimum contact pressure at the interface between the wall structure and the foundation soil.

Htotal=Total horizontal driving forces.FSs=Factor of safety against sliding.

B = Base width of the wall. E = Eccentricity of the resultant force.

Mrs,Mrt,Mrh,Mrk = Flexural strength of stem,toe,heel,shear key.

Ms,Mt,Mh,Mk= Maximum bending moment at the face of the wall, toe of slab, heel of slab, shear key.

Vs, Vt, Vh, Vk = design shear carrying capacity at stem, toe, heel, shear key.
Vus, Vut, Vuh, Vuk = Shear capacity of concrete at stem, toe, heel, shear key.

As, At, Ah, Ak = Area of reinforcement at stem, toe, heel, shear key.
ds,dt,dh,dk = Effective depth at stem, toe, heel, shear key.

Cs is the unit cost of steel, Cc is the unit cost ofconcrete, Wst is the weight of steel per unit length ofthe wall, and Vc is the volume of concrete per unit.

The below table shows the rates for different grades of concrete and steel, as per Hubli- Dharwad schedule rates book.

Grade of concrete in N/mm2	Rate in rupees per cubic meter
M20	□5200
M30	□6000
M40	□6600

Grade of steel in N/mm2	Rate in rupees per kilogram
415	□ 55
500	□ 60

V. Results And Discussion

Example: [1]

A cantilever retaining wall to retain earth for a height of 4m. The backfill is horizontal. The density of soil is 18kN/m^3. S.B.C of soil is200 kN/m^2. The co-efficient of friction between concrete and soil as 0.6. The angle of repose is 30°. Use M20 concrete and Fe415 steel.

1. Parametric studies on effect of change in cost of retaining wall for various grades of concrete for 4 mts height.

Table 5.1. Cost of retaining wall for various grades of concrete.

SL NO	CONCRETE GRADE	WEIGHT (KN)	Optimum design variables												Cost Rs/mts
			X1	X2	X3	X4	X5	X6 $*10^{-3}$	X7 $*10^{-3}$	X8 $*10^{-3}$	X9	X10	X11	X12 $*10^{-3}$	
1	M20	48.132	2.41	0.95	0.3	0.2	0.37	2.5	2.51	4.71	2.04	0.34	0.37	1.00	**16000.0**
2	M30	46.5842	2.50	0.80	0.2	0.2	0.37	5.6	2.30	2.01	1.86	0.31	0.33	0.55	**16500.0**
3	M40	47.0307	2.50	0.86	0.2	0.2	0.37	3.6	0.792	4.71	2.04	0.35	0.35	0.55	**17500.0**

• Weight of the retaining wall does not show significant changes for different grade of concrete.

Note: 1) X1, X2, X3, X4, X5, X9, X10, X11, are geometric variable which are expressed in meters.

2) X6, X7, X8, X12, are reinforcement variable which are expressed in sq. meters.

2.Parametricstudies on effect of change in retaining wall, heights for M20 grade of concrete.

Table 5.2: Optimum design variables for different heights for M20 grade concrete.

SL NO	HEIGHT mts	WEIGHT (KN)	Optimum design variables												Cost Rs/mts
			X1	X2	X3	X4	X5	X6 $*10^{-3}$	X7 $*10^{-3}$	X8 $*10^{-3}$	X9	X10	X11	X12 $*10^{-3}$	
1	4.00	**48.132**	2.412	0.95	0.23	0.2	0.36	2.5	2.51	4.71	2.04	0.34	0.37	1.00	**16000.0**
2	5.00	**65.065**	3.00	0.92	0.2	0.2	0.46	7.23	7.23	4.71	2.43	0.40	0.32	0.792	**21500.0**
3	6.00	**113.59**	4.15	1.47	0.35	0.2	0.60	10.0	4.712	2.51	3.05	0.40	0.35	1.23	**28700.0**
4	7.00	**131.62**	5.00	1.56	0.43	0.2	0.70	12.0	6.4	4.67	3.07	0.46	0.50	1.5	**37900.0**

- Weight to height ratio is 12.03, 13.013, 18.9, and 18.8.

Note:1) Parameters such as SBC= 200 kN/m2, γ= 18 kN/m3, μ=0.6, φ=30°.

3. Optimum cost and variables of retaining wall.

Table7.3.1: optimum cost and variables for 4 m height and M20 grade of concrete.

SL NO	CONCRETE GRADE	HEIGHT mts	WEIGHT (KN)	Optimum design variables												Cost Rs/mt
				X1	X2	X3	X4	X5	X6 $*10^{-3}$	X7 $*10^{-3}$	X8 $*10^{-3}$	X9	X10	X11	X12 $*10^{-3}$	
1	M20	4.00	72.25	3.0	0.75	0.40	0.2	0.4	2.61	1.25	0.75	-	0.5	0.23	0.75	**17,350.0**
Before optimization of retaining wall																
3	M20	4.00	48.13	2.41	0.95	0.23	0.2	0.3	2.5	2.51	4.71	2.0	0.34	0.37	1.00	**16,000.0**
After optimization of retaining wall																

Note: 1) Parameters *such asSBC= 200 kN/m2, γ= 18 kN/m3, μ=0.6, φ=30°.*

VI. Conclusion

- Genetic algorithm can be satisfactorily applied for the optimization of cantilever retaining wall.
- There is sudden change is observed for weight and height ratio, between 5mts and 6mts
- Weight of the retaining wall has been reduced from 72.25 KN to 48.13KN.
- Some geometric parameters of retaining wall have been reduced and some are increased.
- Cost of retaining wall has reduced from 17,350 to 16,000 Rs/mts of length.

Reference

[1]. Design of reinforced concrete structure by M.L.Gambhir:PHI Publication.
[2]. Prof.Sable K.S, Miss Patil Archana A. -(2012)"Optimization of retaining wall by using optimum tool in mat lab"(IJERT)ISSN 2278-0181,Vol. 1 Issue 6.
[3]. Mohammad Khajehzadeh and Mahdiyeh Eslami (2012) "Gravitational search algorithm for optimization of retaining structure".Vol. 5 No. 1 (IJST) ISSN: 0974- 6846
[4]. E.K P. Chong, An Introduction to optimization, A Wiley-lnter science Publication.
[5]. Schedule rate Hubli-Dharwad.karnataka,India.
[6]. S.R.and.C.S.Krishnamoorthy "Gentic algorithm-based methodolgis for design," Jr structural engineer(1997).
[7]. IS 456: 2000 'PLAIN AND REINFORCED CONCRETE CODE OF PRACTICE'

Mithun K Mhalsekar."Optimization of Cantilever Retaining Wall Using Genetic Algorithm Method." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 16, no. 4, 2019, pp. 01-07