ANALYSIS AND DESIGN OF STRUCTURAL PRECAST INTERLOCKING BLOCKS FOR RETAINING WALL

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Abstract— **The worldwide usage of retaining wall has stimulated a research for appropriate, easy, fast and cost-effective new ways of wall construction. Mortarless technology using interlocking bricks is very promising among many technologies. This can only be achieved with the concept and implementation of sustainability of wall towards the pressure exerted by soil. The study done and shown in this paper is one such paradigm towards sustainability of wall. The study in this paper is done on the design concept, modeling of interlocking structural block, using it as a retaining wall. The strength parameters of these walls are checked by ansys software. These blocks can easily transferred from one place to another. This report is about such interlocking walling technology and in particular: how to improve speed of wall-construction, the effects of brick design on wall alignment accuracy and wall behavior (principle stress, deformation) when subject to lateral forces. This research paper consist of an analytical study of a retaining wall made up of the interlocking precast structural blocks in ansys software. In this paper the design of the brick is been prepared by keeping into consideration various interlocking patterns and their strengths. Retaining wall of these designed interlocking brick is been constructed using ansys software. Various heights of this retaining wall is been considered (ie 2m, 3m,4m). In order to perform the analysis of this wall, two cases are considered. 1) All sides are fixed. 2) Only bottom is fixed. The retaining wall is been designed on the basis of earth pressure exerted on it. This earth pressure further depends upon various conditions. Hence both the cases are divided into five parts. I) Dry leveled back fill. II) Two layred leveled backfill. III) Submerged leveled backfill. IV) Leveled backfill with uniform surcharge. V) Backfill with inclined surface. All these cases are further analyzed by the ansys software**

Keywords— **Retaining wall, mortarless technology, interlocking, ansys software, principal stress, deformation, normal stress.**

1. INTRODUCTION

The concept of precast (also known as "prefabricated") construction includes those buildings, where the majority of structural components are standardized and produced in plants in a location away from the building, and then transported to the site for assembly. These components are manufactured by industrial methods based on mass production in order to build a large number of buildings in a short time at low cost. Precast concrete is a construction product produced by casting concrete in a reusable mold or "form" which is then cured in a controlled environment, transported to the construction site and lifted into place. In contrast, standard concrete is poured into site-specific forms and cured on site.

Modular construction has been widely adopted for low-to-medium-rise buildings, but fairly limited for high rises. A particular knowledge gap resides with the lateral force resistance of modular high-rises. Most such buildings adopt cast-in-situ cores for lateral force resisting, which is still labor-intensive. This paper aims to develop a new lateral force resisting system using precast shear walls as part of the modules for high-rises.

2. METHEDOLOGY

In this research paper analytical study of Precast retaining wall is been carried out. This wall is made up of precast structural blocks, and it is compared with precast RCC wall. It was observed that, conventional precast retaining wall is very uneconomical and very heavy to travel from one place to another. Hence in order to avoid such problems, paradigms of structural precast interlocking blocks are prepared. These blocks are designed and analysed by ANSYS software. These blocks are further interlocked and retaining wall is been formed. Further this retaining wall is been

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analysed for different heights and different soil conditions.

3. DETAILED STUDY

3.1 RETAINING WALL

Retaining walls are relatively rigid walls used for supporting soil laterally so that it can be retained at different levels on the two sides. Retaining walls are structures designed to restrain soil to a slope that it would not naturally keep to (typically a steep, near-vertical or vertical slope). They are used to bound soils between two different elevations often in areas of terrain possessing undesirable slopes or in areas where the landscape needs to be shaped severely and engineered for more specific purposes like hillside farming or roadway overpasses. A retaining wall that retains soil on the backside and water on the front side is called a seawall or a bulkhead.

3.2 CLASSIFICATION OF RETAINING WALL

- Gravity wall-Masonry or Plain concrete
- Cantilever retaining wall-RCC (Inverted T and L)
- Counterfort retaining wall-RCC
- Buttress wall-RCC

3.3 EARTH PRESSURE

Earth pressure is the pressure that soil exerts in the horizontal direction. The lateral earth pressure is important because it affects the consolidation behavior and strength of the soil and because it is considered in the design of geotechnical engineering structures such as retaining walls, basements, tunnels, deep foundations and braced excavations.

The coefficient of lateral earth pressure, K, is defined as the ratio of the horizontal effective stress, σ'h, to the vertical effective stress, σ'v. The effective stress is the intergranular stress calculated by subtracting the pore pressure from the total stress as described in soil mechanics. K for a particular soil deposit is a function of the soil properties and the stress history. The minimum stable value of K is called the active earth pressure coefficient, Ka; the active earth pressure is obtained, for example, when a retaining wall moves away from the soil. The maximum stable value of K is called the passive earth pressure coefficient, Kp; the passive earth pressure would develop, for example against a vertical plow that is pushing soil horizontally. For a level ground deposit with zero lateral strain in the soil, the "at-rest" coefficient of lateral earth pressure, K0 is obtained.

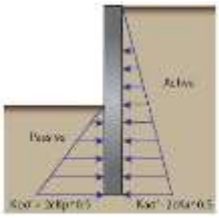

Fig.1 Pressure acting on retaining wall

3.4 TOUGHNESS OF WALL

- The strength of precast concrete gradually increases over time.
- Other materials can deteriorate, experience creep and stress relaxation, lose strength, deflect over time and may not be able to withstand vehicular impacts.
- The load-carrying capacity of precast concrete is derived from its own structural qualities and does not rely on the strength or quality of the surrounding backfill materials.
- Studies have shown that precast concrete products can provide a service life in excess of 100 years. In severe conditions, additional design options are available to extend the life of concrete products.

3.5 VARIOUS FACTORS AFFECTING EARTH PRESSURE.

Earth pressure depends on type of backfill, and the height of wall and the Soil conditions:

The different type of soil conditions are considered as various cases as follows.

Case 1. Dry leveled back fill.
Case 2. Two layred leveled backfill.
Case 3. Submerged leveled backfill.
Case 4. Leveled backfill with uniform surcharge.
Case 5. Backfill with inclined surface.
CASE A and **CASE B** both cases are analised for all the above conditions.

CASE A : All sides of retaining wall are fixed
CASE B : Only bottom of Retaining wall is fixed.

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Table 1 Internal Friction And Unit Weight Of Soil

Type of soil	**Ø**	**ɣ (Kn/m)**
Dry leveled back fill.	30º	18
Two layred leveled backfill.	Ø1=30º Ø2=28º	γ_1=18 γ_2=12.19
Submerged leveled backfill.	30º	γ_1=18 γ_2=12.19
Leveled backfill with uniform surcharge.	30º	18
Backfill with inclined surface.	30º	18

Where :

Ø = Internal friction of soil

Ø = Internal friction of first layer of soil

Ø2 = Internal friction of second layer of soil.

ɣ = Unit weight of soil

4. PRECAST RETAINING WALL

Interlocking bricks are the enhanced form of conventional method of casting. Each block is constructively designed to lock itself to the other block around without the use of mortar. High quality interlocking bricks are made of cement, sand and Stone dust mixed together in appropriate proportions. The required materials are batched and mixed proportionately. Once the required mix is prepared, it is then compressed to form bricks with desirable interlocking pattern.

Depending upon the magnitude of the pressure the design of the retaining wall varies, simultaneously Area of steel in the wall also varies. As large amount of steel is required in these type of retaining walls, large amount of financial support is required. Hence to avoid this problem we have decided to create the precast interlocking retaining blocks, which will be used to form a retaining wall, depending upon the interlocking basis. In this research work, to make the retaining wall most economical, the wall is made steel free and interlocking system is such developed that it can resist more efficiently then the conventional retaining wall.

5. DESIGN AND CONCEPT OF PRECAST INTERLOCKING BLOCK.

The conventional precast retaining wall which is being used at mass level are having many issues. There are some disadvantages to precast concrete. They are discussed below.

1. High Initial Investment: For installing a Precast Concrete plant, heavy and sophisticated machines are necessary which requires a high initial investment. A large scale of precast construction projects must be available to ensure sufficient profit.
2. Transportation Issue: The construction site can be at a distant location from the Precast Concrete plant. In that case, the precast members must be carried to the site using trailers. In many cases, the reduced costs of Precast Concrete are compensated by the transportation cost.
3. Handling Difficulties: Proper care and precaution have to be taken for handling precast concrete. Usually, precast members are heavy and large which makes it difficult to handle without damage. Generally, portable or tower cranes are used to handle precast members.
4. Modification: Limitation In case of precast structures, it is difficult to modify the structure. For example, if a structural wall is to be dismantled for modification it will impact the overall stability of the structure.
5. Sensitive Connection Works: Assembling of the precast members is one of the key points for ensuring strong structural behavior. Connections between several structural members must be supervised and done properly to ensure the intended behavior of the connection such as simple, semi-rigid or rigid connections. Besides this, faulty connections may lead to water leakage and fail sound insulation.

So to avoid all these issues we have come across with the new design of the interlocking blocks. These blocks are prepared in ANSYS software and analyzed too.

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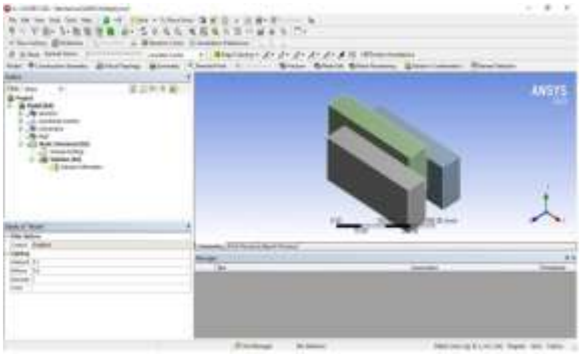

Fig 2 Design of precast interlocking block (3D view)

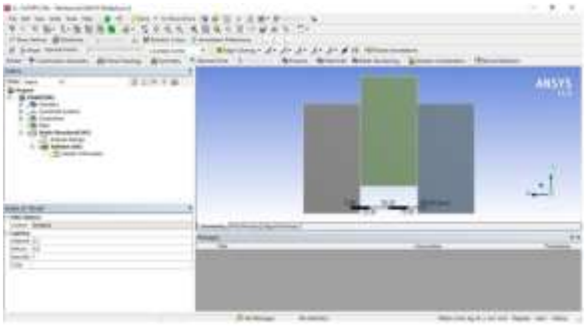

Fig 3 Side view of the block

The design of the structural block is prepared as shown in figures above. These blocks were made by using ANSYS software.

6. EXPERIMENTATION WORK AND ANALYSIS

1. The design of the brick is been prepared by keeping into consideration various interlocking patterns and their strengths.

2. This brick is then converted into a retaining wall.

3. Two cases of walls are considered as follows:

- **CASE A:** All sides are fixed.
- **CASE B:** Only bottom is fixed.

4. These cases are further analyzed for three various heights which are 2m, 3m & 4m.

M50 grade of concrete is been used in software for the preparation of the blocks. Grades of concrete are defined by the strength and composition of the concrete, and the minimum strength the concrete should have following 28 days of initial construction. The grade of concrete is understood in measurements of MPa, where M stands for mix and the MPa denotes the overall strength.

Table 2 Active pressures calculated at various heights and cases

Height / Case	Pressure 2m (Mpa)	Pressure 3m (Mpa)	Pressure 4m (Mpa)
1	0.012	0.018	0.024
2	0.009	0.014	0.020
3	0.008	0.012	0.016
4	0.027	0.033	0.039
5	0.013	0.020	0.026

6.1 Modeling in ANSYS

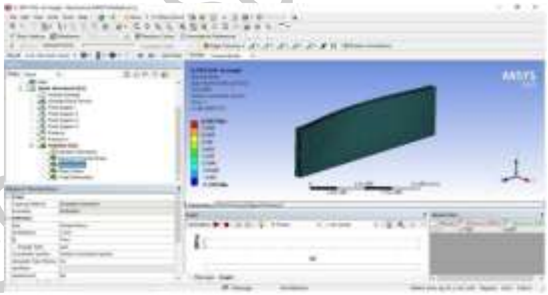

Fig. 4 Position of normal stress acting on wall of 2 m height

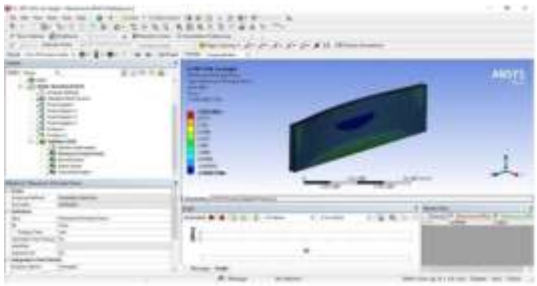

Fig. 5 Position of Maximum principle stress acting on wall of 2m height

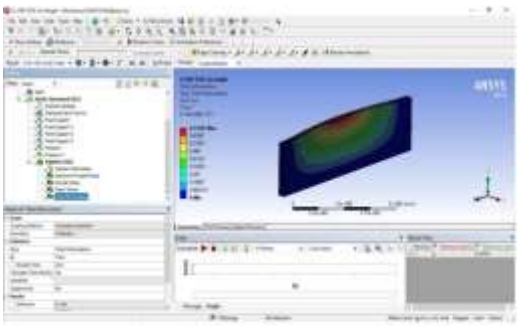

Fig. 6 Position of total deformation acting on wall of 2m height

In above way the analysis is been done using Ansys software and the results are as shown in following tables.

7. OBSERVATIONS

A. All sides are fixed (Case A)

Case 1. Dry levelled back filled

Table 3 Maximum principal stress, normal stress and total deformation of wall at various heights

Height in m	Maximum principal stress (Mpa)	Normal stress (Mpa)	Total deformation (mm)
2	7.69	6.62	0.74
3	4.92	4.87	0.12
4	5.31	4.24	0.11

Case 2. Two layered leveled backfill.

Table 4 Maximum principal stress, normal stress and total deformation of wall at various heights

Height in m	Maximum principal stress (Mpa)	Normal stress (Mpa)	Total deformation (mm)
2	0.64	0.55	0.06
3	2.37	1.62	0.09
4	4.32	3.81	0.09

Case 3. Submerged leveled backfill.

Table 5 Maximum principal stress, normal stress and total deformation of wall at various heights

Height in m	Maximum principal stress (Mpa)	Normal stress (Mpa)	Total deformation (mm)
2	0.58	0.49	0.05
3	1.81	1.38	0.08
4	7.66	3.86	0.12

Case 4. Leveled backfill with uniform surcharge.

Table 6 Maximum principal stress, normal stress and total deformation of wall at various heights

Height in m	Maximum principal stress (Mpa)	Normal stress (Mpa)	Total deformation (mm)
2	1.92	1.65	0.18
3	13.2	5.41	0.21
4	9.08	7.22	0.18

Case 5. Backfill with inclined surface.

Table 7 Maximum principal stress, normal stress and total deformation of wall at various heights

Height in m	Maximum principal stress (Mpa)	Normal stress (Mpa)	Total deformation (mm)
2	0.95	0.82	0.09
3	3.42	1.95	0.14
4	7.04	6.21	0.12

B. Only bottom is fixed. (Case B)

In the above way the analysis of the wall is been done and similar analysis is carried out for the wall having only bottom side fixed, and the remaining sides are kept free.

Case 1. Dry levelled back filled

Table 8 Maximum principal stress, normal stress and total deformation of wall at various heights

Height in m	Maximum principal stress (Mpa)	Normal stress (Mpa)	Total deformation (mm)
2	21.15	13.38	1.01
3	9.14	5.28	0.8
4	6.25	5.1	1.53

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Case 2. Two layred leveled backfill.

Table 9 Maximum principal stress, normal stress and total deformation of wall at various heights

Height in m	Maximum principal stress (Mpa)	Normal stress (Mpa)	Total deformation (mm)
2	1.76	1.11	0.08
3	3.64	2.97	0.7
4	10.25	5.9	1.26

Case 3. Submerged leveled backfill.

Table 10 Maximum principal stress, normal stress and total deformation of wall at various heights

Height in m	Maximum principal stress (Mpa)	Normal stress (Mpa)	Total deformation (mm)
2	1.59	1	0.07
3	3.16	2.58	0.55
4	15.58	8.63	2.09

Case4. Leveled backfill with uniform surcharge.

Table 11 Maximum principal stress, normal stress and total deformation of wall at various heights

Height in m	Maximum principal stress (Mpa)	Normal stress (Mpa)	Total deformation (mm)
2	5.28	3.34	0.25
3	8.53	6.97	1.66
4	10.16	8.29	2.49

Case 5. Backfill with inclined surface.

Table 12 Maximum principal stress, normal stress and total deformation of wall at various heights

Height in m	Maximum principal stress (Mpa)	Normal stress (Mpa)	Total deformation (mm)
2	2.63	1.65	0.12
3	10.18	5.87	1
4	6.95	5.68	1.7

C. Comparison of RCC and Precast Retaining wall

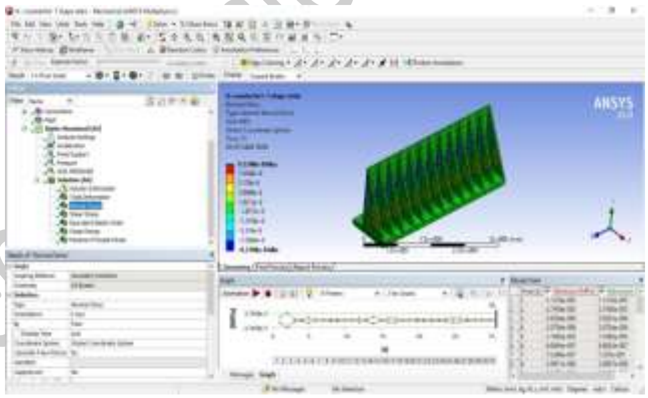

Fig 7. Normal stress acting on RCC wall

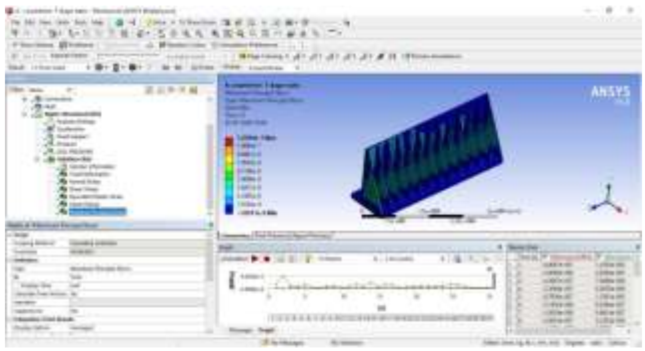

Fig 8 Maximum principal stress acting on RCC wall

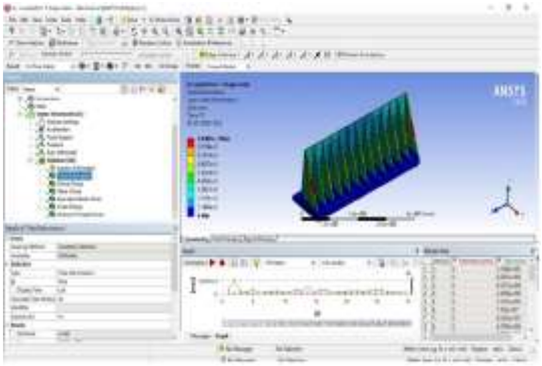

Fig 9. Total Deformation acting on wall

Table 13 Total Deformation

	Total Deformation mm	
Time	**Precast**	**R.C.C.**
1	5.19E-13	6.65795E-13
2	3.73E-06	4.77642E-06
3	5.79E-07	7.42896E-07
4	3.06E-07	3.92132E-07
5	1.16E-06	1.49107E-06
6	6.83E-08	8.75345E-08
7	7.30E-08	9.35946E-08
8	3.97E-07	5.08913E-07
9	6.10E-07	7.82377E-07
10	1.31E-07	1.68168E-07

Table 13 Max. Principal Stress Mpa

Max. Principal Stress Mpa		
Time	**Precast**	**R.C.C.**
1	2.74E-12	3.50975E-12
2	1.85E-05	2.37692E-05
3	2.88E-06	3.69706E-06
4	1.52E-06	1.95136E-06
5	5.79E-06	7.42012E-06
6	3.40E-07	4.35626E-07
7	3.63E-07	4.65841E-07
8	1.98E-06	2.53268E-06
9	3.04E-06	3.8936E-06
10	6.53E-07	8.36959E-07

Table 14 Normal stress (Mpa)

Normal Stress Mpa		
Time	**Precast**	**R.C.C.**
1	5.87E-13	7.5306E-13
2	1.60E-05	2.04587E-05
3	2.48E-06	3.18199E-06
4	1.31E-06	1.67957E-06
5	4.94E-06	6.33745E-06
6	2.90E-07	3.72068E-07
7	3.10E-07	3.97822E-07
8	1.69E-06	2.16308E-06
9	2.59E-06	3.32548E-06
10	5.58E-07	7.1482E-07

In above tables we compare RCC wall to precast wall for Total Deformation, Normal stress, Max. Principal Stress. And we conclude that all results for the precast wall is less than RCC wall by average 10-15% so precast wall is recommended

8. RESULTS AND DISCUSSIONS

- The concept, design and application of interlocking precast block design will prove effective example for sustainable approach towards construction.
- According to the analysis done in the ANSYS, it is clearly seen that the deformation of the retaining wall is produced less than 3mm which is quiet safe enough.
- It is clearly observed that, when the RCC wall is compared with the precast wall stresses induced in the precast wall are very less as compared to RCC wall.
- These blocks are easy to transport and they are easy to construct
- The key factors which regulate the quality of construction such as curing, temperature, mix

design, formwork, etc. can be monitored for Precast Concrete. So, improved quality construction can be performed.

- The simplified construction process reduces the time, increases the productivity, quality and safety and thus the cost is reduced.
- Precast Concrete structure has a longer service time period and minimal maintenance. The high-density Precast Concrete is more durable to acid attack, corrosion, impact, reduces surface voids and resists the accumulation of dust.

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