

# NUMERICAL MODELLING AND ANALYSIS OF RETAINING WALL WITH CRUMB RUBBER AS BACKFILL

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**Abstract** – To provide resistance to overturning and sliding, cantilever retaining wall having thinner stem utilizes the weight of the backfill soil. Finite element analysis of L shaped retaining wall with conventional backfill and crumb rubber backfill were modelled and the results were compared in this study. 3D modelling of L shaped retaining wall was done in Plaxis 3D. Small scale model of the retaining wall was developed and its dimensions were fixed. Scrap tyre increases day by day and its disposal is a serious difficulty faced by the society. The best alternative to use scrap tyre in civil engineering terms is to use them as backfill in retaining wall. Crumb rubber of size varying from .075mm to 4.75mm was used in this study. In this study properties of the conventional backfill and crumb rubber were obtained from laboratory test. Crumb rubber was added in various percentages 5, 10, 15, 20, 25 and 30%. Results were compared for all the 7 models.

**Key Words:** L shaped retaining wall, crumb rubber, Plaxis 3D, displacement, earth pressure.

## 1. INTRODUCTION

More than 1 million rubber tyres are being discarded every year in India. The safe disposal of scrap tires is a growing environmental concern. These non biodegradable tires occupy wide range of space when dumped in landfills. Civil engineering field has done various researches on the reuse of scrap tyre and great benefits are achieved for engineers and the society as a whole. To prevent the retaining wall against failing it should withstand the lateral pressure acting on them by the soil. Using waste tyre as backfill in the form of crumbs is a promising method of recycling this waste material in an economical and ecofriendly manner. Recycled rubber produced from automobile scrap tyre is called crumb rubber. A granular consistency is maintained and it is recycled after removing steel and tyre cords. Abdel Salam et al. [1] conducted a reliability analysis to obtain the partial resistance factors needed for the main EPS properties. Partial resistance factors for the EPS mechanical parameters were calculated in their study. The results were then used in a 3D finite element model using the software PLAXIS 3D to simulate the behaviour of flexible walls with EPS inclusion under static load. High reduction in lateral pressure was obtained which was dependent on the thickness of EPS. The results obtained were verified using a physical model in laboratory. A Rouili et al. [7] conducted numerical analysis on different wall geometries. From the results in his study the proportioning control the equilibrium between the translation of the wall toe and the instantaneous rotation.

The average value between at-rest and active pressure determines the lateral pressure which are proposed by most design standards, is found not to be applicable for all walls. Ravichandran et al. [6] studied the engineering properties of the shredded tyre and designed retaining walls for static and dynamic namely seismic conditions. The average properties were obtained by LRFD method and were compared with conventional granular material. Retaining wall backfilled with shredded tires was investigated by applying design earthquake acceleration time histories using advanced finite element software and compared to that of sand backfill. Their results report that the shredded tire backfill significantly reduces the wall tip deflection and maximum shear force and bending moment along the wall.

## 2. MATERIALS USED

Materials used for the study includes river sand and crumb rubber. The parameters of soil that influence the earth pressure must be evaluated before the actual design. These include the unit weight, angle of friction and the cohesion intercept. By determining these parameters, the lateral earth pressures can be determined theoretically. After determining the earth pressures, stability check against sliding, overturning, bearing capacity failure & tension can be done. In this study river sand is used which is collected from Kottayam, Kerala. The properties of the soil were determined as per IS specifications. From the particle size distribution it is classified as poorly graded sand. In this study crumb rubber used varies from 4.75mm to 0.075mm and it was collected from Kottayam, Kerala. Particle size distribution analyzed same gradation as that of river sand. The gradation of crumb rubber is comparable to the gradation of sandy or gravelly soils commonly used as backfill materials. From the perspective of gradation, the shredded tires are considered acceptable backfill material for retaining walls.

## 3. SCALE DOWN OF RETAINING WALL

To resist the lateral earth pressure of soil retaining wall is designed and constructed. In this study L shaped retaining wall is considered and it is scaled down for the analysis. In this study only sliding failure is considered. After various trial and error the dimensions of the scaled down retaining wall was obtained as height of wall as 36cm, thickness of stem as 3mm, thickness of base slab as 4mm and width of toe slab as 20cm. Aluminium was considered as the retaining wall in analysis.

#### 4. METHODOLOGY

Crumb rubber was added to the sand in 5%, 10%, 15%, 20%, 25% and 30% by weight of sand and laboratory tests were conducted for sand tyre mixtures. All the laboratory tests conformed to IS specifications. Finite element analysis of the model study was done in Plaxis 3D. Mohr Coulomb soil model was selected. The Linear-Elastic Perfectly-Plastic Mohr-Coulomb model involves five input parameters, i.e. Young's modulus (E) and Poisson's ratio ( $\nu$ ) for soil elasticity, cohesion (c), friction angle ( $\phi$ ) and dilatancy angle ( $\psi$ ) for soil plasticity. Constant average stiffness is estimated for each layer. Constant stiffness makes the computations relatively fast and obtains a first estimate of deformations. Boundary values are provided as same as the tank dimension. In the soil model phase foundation bed of 12 cm is provided and on top 6 layers of 6 cm is provided and assigned the properties of sand for the first case. For rest of the models, properties of sand added with crumb rubber were assigned. All these properties assigned are obtained from the tests conducted in laboratory. In the structure phase wall is modelled as a plate and aluminium as material is assigned. Unit weight and young's modulus of aluminium are 27.4kN/m<sup>2</sup> and 69000kN/m<sup>2</sup> Surface is load is created on the backfill and value is assigned. The model is meshed with medium mesh size. In staged construction foundation bed was activated in initial phase, and then each layer was activated in each phase. Finally plate and surface load was activated and the model was analysed and results were obtained. All the model phases are as shown below

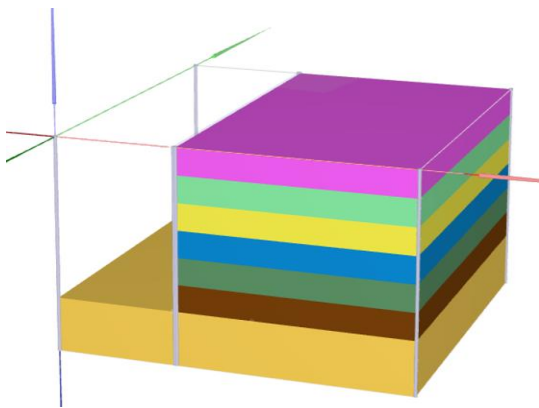


Fig -1: Soil model with sand backfill

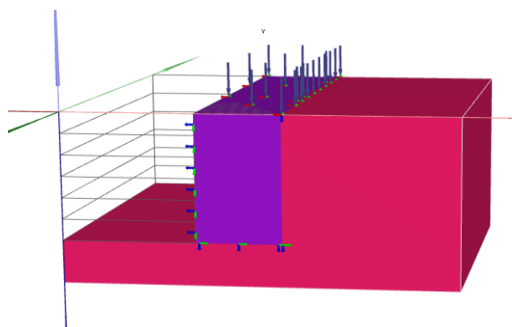


Fig -2: Soil model with sand + crumb rubber backfill

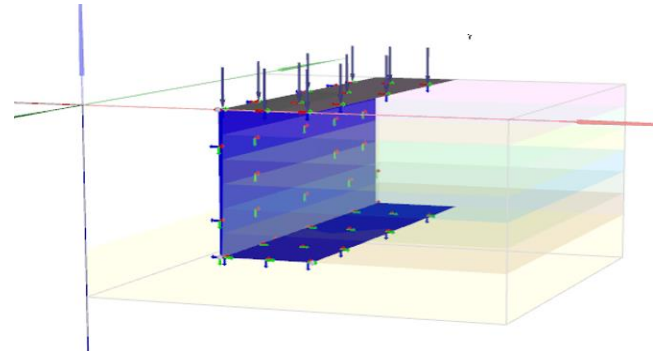


Fig -3: Retaining wall in structure phase

#### 5. MATERIAL PROPERTIES

The properties of sand, crumb rubber and their mixture was obtained from laboratory test and its results are as follows

Table -1: Properties of sand and crumb rubber

Property	Sand	Crumb rubber
Density (g/cc)	1.82	1.31
Angle of internal friction	34°	45°
Cohesion (kg/cm <sup>2</sup> )	0	0.03
Dilatancy angle	5°	16°
Young's modulus (kN/m <sup>2</sup> )	20000	450000

Table -2: Properties of sand + crumb rubber

Property	5%	10%	15%	20%	25%	30%
Density (g/cc)	1.75	1.67	1.61	1.59	1.52	1.42
Angle of internal friction	36°	38°	40°	41°	43°	45°
Dilatancy angle	6°	8°	10°	11°	13°	15°

From the laboratory test results, density and angle of internal decreases as addition of percentage of crumb rubber increases.

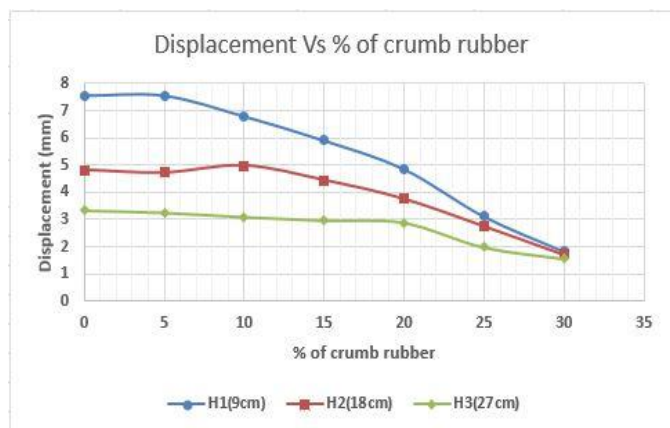
#### 6. RESULTS AND DISCUSSION

In order to validate the results procured from experimental study, Plaxis 3D was used. Soil modelling was done and properties procured from laboratory test were assigned. In structure model, wall was created and property of aluminium was assigned. After meshing, in staged construction soil and wall were activated and in the last phase surface load was activated and the results were obtained. Surface load of 1.5kN/m<sup>2</sup> was applied on the backfill portion. Results were analysed for 3 heights 9cm, 18cm and 27cm from top of wall. The results are tabulated below. When load is applied to sand backfill, displacement was 7.56cm. As crumb rubber was added in increasing percentage displacement value decreased. This decrease in value was noted for all the three depths. Figure 5 shows the

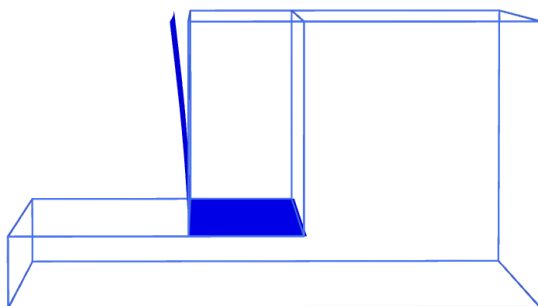
top wall displacement. The difference between the wall top displacement for a surcharge load with only sand and with 30% crumb rubber was almost 76%. As displacement value decreases when crumb rubber is added its can also be explained in terms of lateral earth pressure. Lateral earth pressure decreases when crumb rubber is added. Since rubber has low density, it can be used as a light weight backfill.

**Table -3:** Results from Plaxis 3D

Depth → % of tyre ↓	Displacement (mm)		
	9cm	18cm	27cm
0	7.56	4.82	3.34
5	7.56	4.72	3.26
10	6.80	4.98	3.10
15	5.91	4.45	2.97
20	4.86	3.76	2.89
25	3.12	2.76	1.98
30	1.83	1.72	1.56



**Fig -4:** Graphical representation of results from Plaxis 3D



**Fig -5:** Wall displacement

## 7. CONCLUSIONS

- As density decreases with increase in percentage of crumb rubber it can be used as a light weight backfill in retaining wall.
- Angle of internal friction increases as percentage of crumb rubber increases and hence it can be used as backfill as it helps to reduce pressure acting on wall. Increase in friction angle reduces coefficient of active earth pressure which in turn reduces lateral earth pressure acting on wall.
- The difference between the wall top displacement for a surcharge load of 1.5kN/m<sup>2</sup> with only sand and with 30% tire chips was almost 76%
- Proper reuse of crumb rubber creates sustainable future and provide solution for proper disposal

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