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Confined Aggregate Concrete

The reuse of Waste Tire Tread Cylinders for Confined Aggregate Concrete

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Abstract—**The potential use of Confined aggregate Concrete (CA) concrete in load bearing columns and bearing walls and in bridge abutment structures is of significant interest in rural and other remote and hard to access locations. CA concrete, made by using an automotive tire cylinder to confine and give lateral support to stone aggregates, increases the aggregates combine load bearing capacity and uses. The reuse of discarded, tread-worn, automotive tires with both side walls removed, is assessed and recommended for use as the confining cylinder.**

Keywords—Rural road, lateral support, increase load bearing capacity, reuse tires, confined

I. INTRODUCTION

The CA concrete cellular unit is vertically integrated by its own weight. When combined, the cylinders and the similar size aggregates become a unitized cell which is laterally confined and integrated into a single, circular; load resisting, and three-dimensional building unit. CA concrete structures are constructed of single or multiple cellular units placed in layers or stacked in columns. Using accepted techniques and process and traditional construction techniques, CA concrete may be designed and constructed to function as foundation, road base, gravity or (MSE) retaining walls or load bearing walls, bridge abutment or pier beam support.

The cylinder increases the load bearing capacity of natural and man-made aggregates by providing direct lateral support. CA concrete is a dry concrete, that is, it does not use water & Portland cement. The aggregates in CA concrete may be composed of any relatively uniform particle-size, natural or manmade material. Same-size aggregates tend naturally to flow together and achieve their maximum density when placed within a confined space, without the use of additional compaction energy. For example, grains, beans, or uniform sized ball bearings or marbles placed within a box or a cylindrical space naturally assume their approximate, maximum density. A stone aggregate collection possessing a range of sizes from small to large, e.g. crusher run limestone, usually requires additional compaction energy to achieve optimum bearing-load density to support loads without excessive settlement.

A. Objectives

- Economic: Reduces initial construction costs and long term maintenance costs reduced up to large extent
- Simple technology/prove Performance: Simple and fast to construct with three times the load supporting capacity of traditional design section and use of unskilled labours.
- Environmentally sensitive: Reuse waste tires and uses less material, energy and water during construction hence GREEN solution.

Fig.1. Tire Tread Cylinder used for CA concrete

B. Abbrevations

CA Concrete: Confined Aggregate Concrete
MSE: Mechanically Stabilized Earth
UTM: Universal Testing Machine
WVDOT: West Virginia Department of Transportation

II. LITERATURE REVIEW

Pavement structures generally consist of four layers: subgrade; sub base; unbounded/bounded base course is to drain out the water, which is can be extremely deleterious to the life of the pavement systems include water infiltrating through cracks in the pavement; water entering longitudinal pavement/shoulder joints; seepage water from ditches and medians; and high ground water table. In flexible pavements, water with fine material can also be pumped out causing enlargement of void spaces in the pavement base. Excessive fines in the gradation make aggregate particles too float in the matrix resulting in low permeability with low stability.

The horizontal load supporting capacity of aggregates, soils and granular materials is dependent on the internal friction that is generated between particles was studied by Tuan-Chun Fu and Roger N.L. Chen, PhD, Test results of stone aggregates Contained in Open–ended steel Cylindrical Pipes, WVDOT, November, 2005. Internal friction allows the granular material to internally support the horizontal portion of the vertical load. Graded crushed stone materials used to support loads in the bases of roads or on unpaved roads surfaces are usually made up of particles of varying sizes so that the internal friction between particles is optimized. For this purpose, aggregate road construction materials usually contain between 5 and 12% very fine 'binder' particles. This is by design so that the graded particles can be compacted together tightly to optimize the internal friction and thus maximize the resulting compacted material's load supporting capacity. Anything that reduces this internal friction will reduce the capacity of the compacted particulate material to support external loads. Water is the most common element that tends to reduce the internal friction between soil particles. This is why the drainage design of a road is so important and why during the rainy season unpaved roads tend to deteriorate.

These CA concrete walls are designed using conservative masonry wall design standards regarding wall height to thickness ratios. In designing and stacking masonry elements engineers follow the general principle of keeping the resultant compressive force within the middle third cross sectional area. Following this principal assures that the stacked, discreet masonry elements will always be compressed against each other throughout the stack. As a wall gets taller it is less likely that the compressive force resultant will fall in the middle third area, primarily due to geometric limits on precision of wall construction and load application proposed by Joseph G. Sweet and Roger H.L. Chen, Ph.D., Results of axial Compression test of Tire/Aggregate Column, WVDOT, Morgantown, WV June, 2007.

III. MATERIALS

A. *Base Course Rinforcement (Waste tire tread Cylinder)*

The tire tread cylinder reinforcing shall be a thin walled, circular, cylindrical segment of a material suitable for absorbing the circumferential tensile stresses resulting from the lateral pressure generated by the weight of the stone and any superimposed dead and live loads.

For the purpose of this specification for tire tread cylinder reinforcing element is a used automobile tire with both the sidewalls removed. The Tire tread cylinder diameters shall not exceed 0.71 m and not be less than 0.61 m. The tire tread cylinder width shall be not less than 0.17 m and not exceed 0.22 m. Passenger car tires shall have side wall removed to within 0.02 m of the surface of the tread. The tire should be of uniform diameter and tread width and have no internal steel for fiber belts exposed in the tread surface.

B. *Stone*

For structural applications and foundations the stone aggregate placed inside the cylinders shall be lime stone or other suitable virgin or recycled stone, recycled asphalt pavement, industrial slag or stone aggregate with comparable compressive strength. In remote areas, local river gravel may be used. For highway use the size of the selected relatively uniform sized stone particle gradation. The use of sand, indigenous granular soil materials or the recycling of existing roadway or shoulders stone base is placed in the cylinder if the material is suitable and without excessive clay fines. Roadway shoulders shall be surfaced on top of the cylinder with of 0.1 m of optimality compacted 0.025 m and 0.040 m crusher run stone aggregate.

IV. METHODOLOGY

The confined tire tread cylinders was made by using three different tire manufacturers and three different filler materials where used aggregates, crushed concrete and soil, each tire was filled with different fillers respectively. The tire was placed on a circular plate and was filled in three layers, each layer was hand compacted then a metal circular bearing plate was placed on the top of the tire tread cylinder. The whole arrangement was kept below UTM for compression loading. The load was applied at constant rate over the CA concrete.

In confined aggregate concrete cell the collection of similar size, aggregate particles functions somewhat like a thick hydraulic fluid. They tend to be a pure compressive material. Except for the friction between them, the particles have little or no lateral tensile strength and they tend to follow like a fluid under compressive forces. The confined aggregate concrete cell is a collection of similar size, aggregate, particles confined by a thin-walled cylindrical segment similar to a hydraulic cylinder. The applied bearing load is analogous to the operation of the piston in a hydraulic cylinder. The aggregate particles transfer the main supported loads downward along the axis of the cylinder to the earth and these particles also transfer the transverse lateral pressure to the cylinder device which is resisted by hoop stress.

Fig.2. CA concrete under Compressive Force

V. RESULTS

The filler transmits significant lateral pressure to the cylinder but it also deflects significantly due to local lateral failure. It is not load head is applied that the deflection is reduced throughout the load cycle while significant lateral pressure is transmitted to the cylinder. With the larger load head a more uniform pressure is applied throughout the filler without local failure. This confirms well know criteria that compacted coarse to medium sand make good foundation material with bearing pressure allowed by some codes.

The role of the cylinder shape in solidifying and integrating the aggregate is not significant unless the applied load covers greater than 80 percent of the cylinder circular area. As the aggregate size remain uniform; the role of the solidifying and integrating the aggregates becomes more effective for smaller loads. With small particles, if the foot print of the load is small, lateral failure can occur at relatively small loads, due to high local stress

The following graphs for these lab tests are as follows:

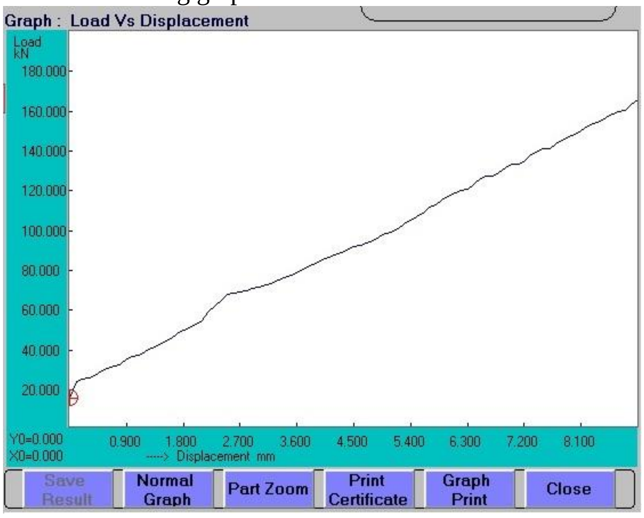

Fig.3. load vs. displacement for sample 1 (aggregates)

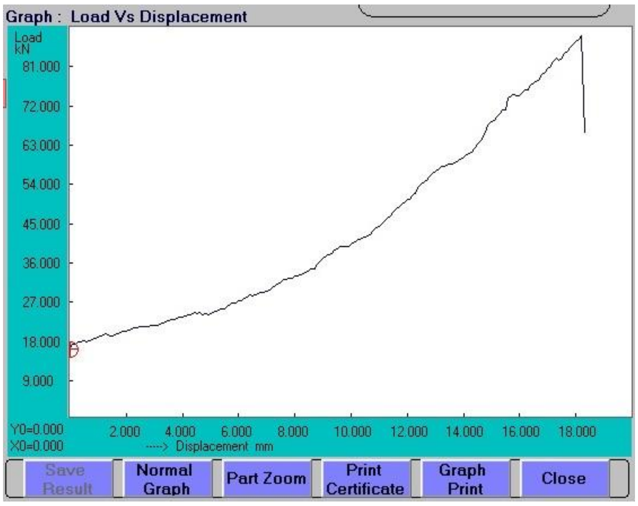

Fig.4. load vs. displacement for sample 2 (crushed concrete)

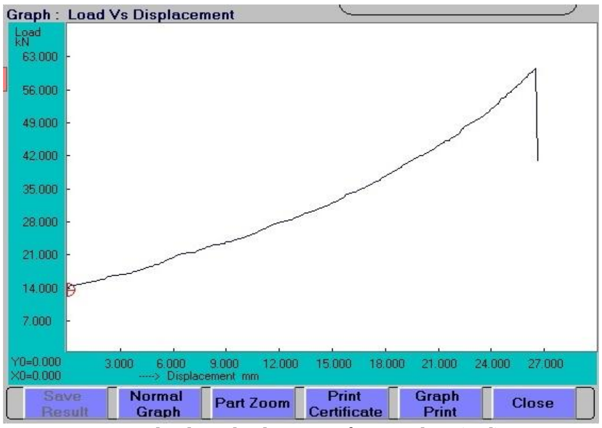

Fig.5. load vs. displacement for sample 3 (soil)

A. Applications of CA Concrete

- Highway bases and shoulders for concrete and asphalt paved roads and stone surface rural roads of all climates subject to the range of loading from low volume to heavy industrial loading.
- Retaining walls and bearing walls including low volume roads bridge piers in remote places
- Drainage and erosion control structures to reduce water run off velocity
- Strom water retention structures
- Bridge pier scour protection
- Railway ballast reinforcing and stabilization
- Permeable retaining walls for repair and reconstruction
- Mining facility structures and conveyor foundations
- Foundation of modular housing
- Earthquake energy absorbing base isolation
- Soft grade stabilization for roads, Railroads, sites and structures
- Military force and facility protection

VI. CASE STUDY

A. Morgan Run Road - a Full Scale Erosion test

The primary field test for erosion is currently in place on an unpaved rural road, Morgan Run Road, in Doddridge County. The Doddridge County WVDOH constructed a 45 m long section of CA Concrete one lane road way in 2006 using 350 cylinders of Mechanical Concrete filled with AASHTO #57 limestone aggregate. The cylinders were laid directly on the existing road base and were not connected to each other.

This roadway section was chosen because of its soft subgrade and its location next to a stream which flooded frequently and the associated high maintenance needs. Since the installation in 2006 the road way has continued to flood an average of 3-4 times per year with as much as 24 inches of flood water running across the surface. During these frequent floods the Mechanical Concrete base has remained basically intact, with less than 5 cylinders being moved or raised by the storm water. More importantly the AASHTO #57 limestone base has remained stable and in place and the ditch line of gabion size stone has stayed in place. According to WVDOH personnel, maintenance of this section after flooding has been reduced by over 50% in labor and materials over pre Mechanical Concrete basic

Fig.6. CA Concrete base

Fig.7. Morgan Run Road Mechanical Concrete Test Section March, 2010

B. TRIAD consulting Engineers Parking Lot,Morgantown, WV USA

A 60 m MSE, retaining wall supports a commercial office with a gas well service pad on a hill side also with a parking lot space. This demonstrated project is over 5 year's old and exceeding all expectations for durability to loadings and weather conditions. This means they are functioning better than predicted and have had no unexpected behavior.

Fig.8. Confined Aggregate Concrete as a Retaining wall

rural, unpaved conditions. This road is frequently used by logging trucks, oil and gas rigs, and other industrial loads.

VII. CONCLUSION

Using a tire tread cylinder, i.e. any standard automotive tire with side walls removed, in a construction application; i.e. where the supported vertical loads are of high range; provides a rugged, very conservative materials engineering approach to confining aggregates in CA concrete.

A variety of additional aggregate/cylinder behavioral observations are further confirmed from these tube tests. These include the fluid like behavior of more uniform size aggregates, and relative independence of larger size aggregates from point load failure.

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