IJARASEM

ISSN: 2395-7852

International Journal of Advanced Research in Arts, Science, Engineering & Management (IJARASEM)

Volume 11, Issue 3, May-June 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

IMPACT FACTOR: 7.583

A Research Article on "Design of 'WBM' road by using Geocell"

Netra Kakade[1], Kajal Malakar[2], Prajwal Halge[3], Aniruddha Shende[4], Abhilash Deshmukh[5],

Prof. Rahul Dhanre[6]

UG Student, Department of Civil Engineering, Agnihotri College of Engineering, Nagthana, Wardha, India[12345]

Assistant Professor, Department of Civil Engineering, Agnihotri College of Engineering, Nagthana, Wardha, India[6]

ABSTRACT- This research paper focuses on the design of Water Bound Macadam (WBM) roads utilizing geocell technology. WBM roads are commonly used in areas where pavement construction materials are limited. Geocells are cellular confinement systems made from high-density polyethylene that are placed beneath the road surface to improve load distribution and stability. The study begins with an overview of WBM road construction and the challenges associated with traditional methods, such as poor load-bearing capacity and susceptibility to erosion. It then introduces geocells as a solution to enhance the performance and longevity of WBM roads. Using practical engineering principles and geotechnical analysis, the paper outlines the design process for incorporating geocells into WBM road construction. Factors such as soil properties, traffic loadings, and environmental conditions are considered to determine the optimal placement and configuration of geocells within the road structure. Furthermore, the study discusses the benefits of using geocells in WBM road design, including improved load distribution, reduced rutting and deformation, and increased resistance to erosion and moisture ingress. These advantages contribute to the overall durability and performance of the road, especially in areas prone to heavy traffic or adverse weather conditions. The findings and recommendations presented in this paper provide valuable insights for engineers and practitioners involved in road infrastructure development. By integrating geocell technology into WBM road design, communities can benefit from cost-effective and sustainable road solutions that withstand the challenges of modern transportation demands.

KEYWORDS-WBM Road, Geocell, Road design, Pavement construction, Stability enhancement, Durability, Sustainability

I. INTRODUCTION

Water Bound Macadam (WBM) roads have long been a staple in road construction, especially in regions where conventional pavement materials are scarce or expensive. Despite their widespread use, traditional WBM roads often face challenges related to load-bearing capacity, durability, and susceptibility to erosion. In recent years, advancements in geotechnical engineering have introduced innovative solutions to enhance the performance and longevity of WBM roads. One such technology is the utilization of geocells, which are cellular confinement systems made from high-density polyethylene. This research paper aims to explore the design aspects and benefits of incorporating geocells into WBM road construction. Geocells offer a promising approach to address the shortcomings of traditional WBM roads by providing improved load distribution, stability, and resistance to environmental factors. The introduction provides an overview of WBM road construction and the limitations associated with conventional methods. It highlights the importance of enhancing WBM road performance to meet the demands of modern transportation infrastructure.

Furthermore, the introduction introduces the concept of geocells and their role in stabilizing and reinforcing the road base. Geocells create a confined space within which aggregate materials are placed, effectively increasing the load-bearing capacity of the road and minimizing deformation under traffic loads. The introduction also outlines the objectives and scope of the research paper, emphasizing the importance of investigating the design considerations and benefits of using geocells in WBM road construction. Additionally, it sets the stage for the subsequent sections of the paper, which will delve into the technical aspects of geocell design, material selection, and performance evaluation. Overall, this research paper seeks to contribute to the body of knowledge on sustainable and cost-effective road construction practices by showcasing the potential of geocell technology in enhancing the performance of WBM roads. Through comprehensive analysis and practical insights, this paper aims to provide guidance for engineers and practitioners involved in road infrastructure development, ultimately leading to the implementation of more resilient and durable transportation networks.

II. LITERATURE REVIEW

[1] Dr. Mohamed Wehbi, Senior Design Engineer, Track Bed Investigation Team, Network Rail Peter Musgrave, Lead Design Engineer, Track Bed Investigation Team, Network Rail the use of Geocell reinforcement to improve the structural performance of the railway track bed in the UK. The railway track is considered to be a structural system which is designed to withstand the combined effects of traffic and the environment so the subgrade is adequately protected (Burrow et al., 2009). To achieve this, the thickness of the ballast and sub-ballast are mainly designed to ensure that the stresses from the dynamic loading are reduced to acceptable levels. In addition to that, other design considerations are taken into account such as subgrade erosion prevention and frost protection. However, when soft subgrades are encountered, the required thickness of track bed layers becomes very large which can impose financial and construction issues. Recent development and detailed understanding in track bed geosynthetics, in particular Geocell reinforcement due to its reinforcement properties, has allowed the reduction of the required thickness of track bed layers. A significant number of research studies have been carried out to investigate the benefits of using Geocells in railway track bed. They have concluded that geocell reinforcement can reduce the granular fill material required by almost up to 40%. Nevertheless, in the UK, the use of Geocells is still limited to a number of bespoke sites; this is due to difficulties related to Geocells design and method of installation. Unfortunately, there is no universally agreed method to design the track bed using Geocells

[2] Gaurav Dhane, Dhiraj Kumar, Akash Priyadarshee-IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE): Geocell an Emerging Technique of Soil Reinforcement in Civil Engineering Field-June 2012
Development of the infrastructure is the most important need in present time. To full fill the infrastructural need of population, small multi-story buildings, express highways, high speed rail tracks, new bridges, airports etc. are required to construct. Ultimately loads from such structure come on the ground. Due to space constrains many times construction takes place on poor soil. Construction over poor soil with high loads is a challenge for civil engineers. Replacement of weak soil by some strong soil or improvement of engineering properties of weak soil by different ground improvement techniques are used in such situation. If such soil cannot be removed or uneconomical to remove then we can use ground improvement techniques. Soil reinforcement is one of the most popular ground improvement techniques. Ease of construction, overall economy and less time consumption are major advantages of soil reinforcement. Use of metal bars, sheet, and strips were traditional form of reinforcement. Geo synthetics are human-made materials made from various types of polymers used to enhance, augment and make possible cost effective environmental, transportation and geotechnical engineering construction projects. They are used to provide one or more of the following functions; separation, reinforcement, filtration, drainage or liquid barrier.

[3] Manish Yadav, Arvind Kumar- Journal of Civil Engineering and Environmental Technology: Application of Geocells in Reinforcement of Soil- August 2014 Soil reinforcement is one of the most popular ground improvement techniques.
Availability of different materials and techniques for reinforcement is one of the major reasons for the continuous increase in the application of the soil Reinforcement. Geocell reinforcement is one of the soil reinforcement techniques. Three dimensional confinements provided by the geocell membrane increase the load carrying capacity of soil. Many works on geocell reinforcement through field study and laboratory test were done by researchers; we show the significant potential of these techniques. Now, geocell are widely being applied in the field of geotechnical engineering, which control erosion of slopes and river banks, enhancing the bearing capacity of retaining structures, pavements, reinforcing soft grounds, protect shores and channel beds.

[4] Biabani, M Mahdi, Behavior of geocell-reinforced sub ballast under cyclic loading in plane strain condition, Doctor of Philosophy thesis, School of Civil, Mining and Environmental Engineering, University of Wollongong, 2015.
Railway plays a key role operating heavy freight transport and passenger services in large and rapidly growing countries such as Canada, Unite States, Australia, India and China. Considering an acceptable ride quality, relatively low cost, compatibility with the environment, and growing demand from industry and commuters, railway has become more popular than other modes of transportation. However, the sustainable development of rail infrastructure does require a significant amount of funding. In order to minimize these costs, innovative ground improvement solutions are necessary. To date, reinforcing track substructure, using planar reinforcement, is commonly used to controlling the lateral spread of ballast and sub ballast and improving the stability of the track during cyclic loading. However, recent studies have shown that geocell can provide much better lateral confinement to infill soil than planar reinforcement.

[5] Naveen.N , D.V.Manoj Kumar- International Journal of Innovative Research in Science, Engineering and Technology: Analysis and Execution of WBM and Bituminous Premix Roads- Vol. 5, Issue 5, May 2016 Road Transport is vital to India's economy.

India's road network carries over 65 percent of its freight and about 85 percent of passenger traffic. Flexible pavement is composed of a bituminous material surface course and underlying base and sub base courses. W.B.M is one type of flexible pavement. When a fast-moving vehicle passes over a W.B.M road, the slurry of Murrum is sucked out by the pneumatic wheel tyres. The stone pieces get disturbed and finally the road surface is disintegrated. Thus the W.B.M roads are not suitable for fast moving vehicles with the wheel Tires. These roads are suitable for slow moving iron wheeled traffic only. In order to overcome this problem now-a days we are applying bituminous layers above the W.B.M to make it better to take the loads, avoid the sucking out of the binding material and to increase the life of the pavement. The thickness off the bituminous layer is depends upon the traffic.

[6] Sandip.S. Patil, S.S. Bachhav, D.Y.Kshirsagar- International Journal of Engineering and Innovative Technology: Use of steel slag in construction of flexible Pavement- Volume 5, Issue 11, May 2016

The large number of Industrial wastes as increased year by year and disposal becomes a very serious problem. It is necessary to utilize the steel slag waste affectively with technical development in each field. Commonly murrum soil has been used for construction of all categories of roads in our country. Although murrum is a good construction material, due to scarcity they increase the construction cost at some parts of the country, several types of murrum soils are found to be unsuitable for road construction in view of higher finer fraction and excessive plasticity properties. Such as used industrial material like steel slag in construction of road pavement. Its disposal causing severe health and environmental hazards in road construction industries is gradually gaining significant importance in India considering the disposal, environmental problems and gradual depletion of natural resources like soil and aggregates. Steel slag is a waste material generated as a by-product during the manufacturing of steel from steel industries. The quantity of generation is around 24 lacs MT per year from (Ref.Report.CRRI-2010) different steel industries in the India. Presently, it has no applications and dumped haphazardly on the costly land available near the plants. In this study, a typical steel slag was collected from an M/s Jindal Steel Industry Pvt. Ltd. Sinnar MIDC, (M.S) in India and its feasibility for use in different layers of road construction was investigated. To improve its Geotechnical engineering properties, the Steel Slag material was mechanically stabilized with locally available soil in the range of 5 – 25%. Geotechnical parameters of these stabilized mixes were evaluated to investigate their suitability in the construction of different layers of road technical specification of steel slag is developed for utilization in the construction of embankment, sub grade and sub base layer of Flexible pavement.

[7] Mohd. Roslihainin, md. Maniruzzaman a. Aziz, zulfiqar ali, ramadhansyah Putra jaya, moetaz m, ei-sergany, haryatiyaacob Steel slag as a road construction Material load, Jurnalteknologi (science & engineering) 73.4 (2015)

Steel slag is a byproduct obtained from steel industry. It is generated as a residue during the production of steel. Because of the high disposal cost as a waste material and the overall positive features of steel slag, it has been declared a useful construction material, not an industrial waste by most of the developed countries. Successively, it is recycled as an aggregate for the construction of roads, soil stabilization, and base and for the surfacing of flexible pavement. Despite this, a large amount of steel slag generated from steel industries is disposed of in stockpiles to date. As a result, a large area of land is being sacrificed for the disposal of this useful resource. Many researchers have investigated the use of steel slag as an aggregate in the design of asphalt concrete for the road construction. The best management option for this by product is its recycling. This leads to reduction of landfills reserved for its disposal, saving the natural resources and attaining a potential environment. The purpose of this paper is to review the engineering properties of steel slag and its utilization for road construction in different ways.

[8] Strength and Rutting Characteristics of WBM with Partial Replacement of Aggregates by Steel Slag Vivek V Gavimath1 , Dr. Sureka Naagesh2 , Dr. H S Jagadeesh3 1 (PG Student, B M S College of Engineering, Bangalore, Karnataka, India) 2 (Professor, B M S College of Engineering, Bangalore, Karnataka, India) 3 (Professor, B M S College of Engineering, Bangalore, Karnataka, India) (year – 2017)

Madhavi Latha, et al., (2010)(1) carried out rutting studies on unpaved roads. They constructed a 2m long and 1m wide unpaved road over a subgrade prepared by in situ natural soil in the IISc campus. A scooter weighing 106kg was moved on it at an average speed of 20kmph. Different reinforcements used in the study were geotextiles, biaxial geogrid, uniaxial geogrid, geocell layer and tyre shreds. They noticed that for same thickness, geocell layer outperformed all others in terms of Traffic Benefit Ratio (TBR). Kiran Kumar, et al., (2012)(2) indigenously built an equipment called Roller Compactor cum Rut Analyzer (RCRA) which is capable of performing both compaction and rutting on a layer. Its outstanding feature is that, it simulates field conditions of compaction and rutting in laboratory. It has a set of vertical and horizontal transducers which are capable of measuring movements and consists of a Programmable Logical Circuit with control screen for monitoring, recording and operating. Bituminous Concrete (BC) grade-2 specimens were prepared using Marshall Hammer, Superpave Gyratory compactor (SGC) and Roller

Compactor cum Rut Analyzer (RCRA). SGC specimens resulted in lowest OBC followed by RCRA for the same binder and air voids. Also, SGC specimens had the highest stability, and those by RCRA were close to SGC. Erol Tutumluer, et al., (2016)(3) conducted cyclic loading test on non-bituminous layer to evaluate effectiveness of geo-synthetic fibre reinforcement in case of unpaved roads. Steel mould measuring 2x2x2m was fabricated to house pavement material to be tested. It was noted that as the thickness of granular layer increases permanent deformation decreases, whereas with increase in number of cycles they noticed severe deformation. In case of geogrid reinforced layer, it was observed that nearer the geogrid from surface lesser was the permanent deformation. In both cases it was clearly evident that for initial loading cycles rate deformation is high and which decreases at later stages of loading.

[10] Strength and Rutting Characteristics of WBM with Partial Replacement of Aggregates by Steel Slag Vivek V Gavimath1, Dr. Sureka Naagesh2 , Dr. H S Jagadeesh3 1 (PG Student, B M S College of Engineering, Bangalore, Karnataka, India) 2 (Professor, B M S College of Engineering, Bangalore, Karnataka, India) 3 (Professor, B M S College of Engineering, Bangalore, Karnataka, India (Jan . Feb. 2018)

Madhavi Latha, et al., (2010) (1) carried out rutting studies on unpaved roads. They constructed a 2m long and 1m wide unpaved road over a subgrade prepared by in situ natural soil in the IISc campus. A scooter weighing 106kg was moved on it at an average speed of 20kmph. Different reinforcements used in the study were geotextiles, biaxial geogrid, uniaxial geogrid, geocell layer and tyre shreds. They noticed that for same thickness, geocell layer outperformed all others in terms of Traffic Benefit Ratio (TBR). Kiran Kumar, et al., (2012) (2) indigenously built an equipment called Roller Compactor cum Rut Analyzer (RCRA) which is capable of performing both compaction and rutting on a layer. Its outstanding feature is that, it simulates field conditions of compaction and rutting in laboratory. It has a set of vertical and horizontal transducers which are capable of measuring movements and consists of a Programmable Logical Circuit with control screen for monitoring, recording and operating. Bituminous Concrete (BC) grade-2 specimens were prepared using Marshall Hammer, Superpave Gyratory compactor (SGC) and Roller Compactor cum Rut Analyzer (RCRA).

III. PROPOSED METHODOLOGY

For study and behavior of loading and settlement we constructed the patch of road at our college campus at size of (3m X 50m X 0.100m).

Material Used: -

We use mainly two types of material in our project for formation of patch

1) Geocell (BY using u v roofing sheet)
2) Steel slag

1. Geocell (HDPE)

Cellular Confinement Systems are popularly known as "Geocells". Geocells are strong, lightweight, three-dimensional systems fabricated from ultrasonically-welded High-Density Polyethylene (HDPE) strips that are expandable on-site to form a honeycomb-like structure. Geocells are filled with compact Non-cohesive soils which are confined within the cellular walls. The composite forms a rigid to semi-rigid structure. The depth of the Geocells as well as the size of each cellular unit can vary as per design requirements. Generally, the infill is sandy or gravelly material. However, the infill may be plain concrete depending on the application such as erosion protection, water channel formation, etc. The surface of the geocell is textured to increase soil-geocell wall friction. The geocell wall is punctured (Fig. 3.1) to assist in immediate dissipation of developed pore water pressures due to increased stresses within the infill of the individual cells.

Geocells can be used to great advantage considering that:

1. Geocells are the only prefabricated three-dimensional geosynthetics with significant third dimension properties
2. They are easily transported as flat strips welded width-wise at regular intervals, and logistics for large quantities is not a problem.
3. Geocells are easy to install and do not require skilled labor. They can be installed in any weather condition.

Fig. 3.1 Geocell

4. The in-fill has essentially to be non-cohesion material; however, the material could be recycled material
5. Solutions considering Geocells as a solution for any civil engineering / geotechnical issue always proves to be cost effective with reduced and economic usage of valuable natural resources, including metal / steel slag, sand, cement, etc. the cost savings can be as substantial as much as 30% for road construction and the time saving can be as much as 50%
6. When used for roads and pavements, geocells substantially reduce cost of maintenance by improving the longevity of the road / pavement

2. UV Roofing sheet

Polycarbonate is the synthetic resin which is made from the polymers which contain carbonate groups. Polycarbonate has excellent physical properties. It has excellent toughness, it has very good heat resistance, it is light weight and easy to handle.

Fig. 3.2 U V roofing sheet

Advantages of Polycarbonate Sheet as a Building and Manufacturing Material-

1) Polycarbonate sheet is the choice of manufacturers in a wide range of industries because of its benefits. One of the most important is its strength combined with design flexibility.
2) Polycarbonate is over 200 times stronger than glass. However, it's also more easily molded than glass and is much lighter.
3) The chemical and scratch resistance of the material is another advantage of polycarbonate sheet.
4) Polycarbonate comes in many different formulations, and this flexibility is yet another one of its benefits.

Actual Procedure:

As requirement of project, we conducted following procedures:

Step1: - Finalized the site for construction of work and mark (3m x50m x 0.075m) Finalized the work site mark it with the lime as actual size of work to be carried out on it.

| ISSN: 2395-7852 | www.ijarasem.com | Impact Factor: 7.583 | Bimonthly, Peer Reviewed & Referred Journal|

| Volume 11, Issue 3, May-June 2024 |

Step 2: - Excavated the marked surface.
For later operations we excavated earth surface about (2m x2.5m x 0.30m)

Step 3: - Lying of slag iron

For lying of geocell layer we formed well compacted base surface by applying compactor on it and form well compacted surface.

Step 4: - Formed the well compacted base surface with steel slag.

Step 5: -Lying of geocell

Then we applied the layer of geocell over well compacted base.

Step 6: - Filled the geocell layer with steel slag (coarser particle)

Step 7: - Rolled and compacted fine steel slag at upper layer of geocell.

For the well compaction of various layers of we applied final compaction for better stability and support.

Step 8: - For smooth movement of traffic, we constructed the top surface by using locally available material (Murrum). It levelled and compacted.

IV. RESULTS & DISCUSSIONS

SETTLEMENT TEST ON PAVEMENT-

Currently, more and more highway projects are launched out to widen or reconstruct the old roads. However, a large number of defects such as longitudinal cracks or lane-to-lane staggering were observed in the pavement shortly after the road construction These defects are believed, according to field investigation, to be caused mainly by the differential settlement between the new and the old roads. Therefore, it is of great practical significance to study the effect of differential settlement on pavement structure of and remedy on it. Understanding Geotechnical investigation of the soil helps to take better decisions leading to the success of the construction project. The height of the building

| ISSN: 2395-7852 | www.ijarasem.com | Impact Factor: 7.583 | Bimonthly, Peer Reviewed & Referred Journal|

| Volume 11, Issue 3, May-June 2024 |

and the use of materials are decided by the engineers on the basis of soil testing reports. The information then leads to strong and durable structures.

1. The subject of pavement distress and failure is considered complex as several factors contribute to the pavement deterioration and failure.: detrimental action in pavements is rapidly increased when excess water is retained in the void spaces of WBM road.
2. In the study the causes of settlement and different distresses will be identified and recommended solution recommended.
3. In the study the causes of settlement and different distresses will be identified and recommended solution recommended. in the study stretch various causes of pavement settlement has been observed. the various test has been carried out on site
4. The test results of in situ soil shows that the soil poor load bearing capacity and moderately susceptible to water ingress. the geometric features of the study stretch shows that there is insufficient lateral and longitudinal slope in the pavement so it is highly water susceptible which leads to pavement failure.

Impact loading test-

1. In this test the impact loading is applied over the centre of the pavement and 20 cm away from all direction from centre.
2. The impact loading is given by standard rammer of a size having bottom, Ø 140mm thickness of bottom 75mm, height of handle 900mm, Ø of handle 25mm and 12.07 kg in weight.
3. Firstly, the rammer is falling from height of 30cm at centre and then fall from another marked point around centre the height of falling rammer is varied and at what distance the maximum settlement cause is then recorded.

Observation table:

Sr. No.	WBM Road With Geocell Reinforced		WBM Road Without Geocell Reinforced	
	Height of Filling (cm)	**Settlement (mm)**	**Height of Filling (cm)**	**Settlement (mm)**
1.	30	-	30	0.24
2.	60	0.24	60	0.5
3.	90	2	90	4
4.	120	4	120	6
5.	150	6	150	8

GRADUAL LOADING TEST

Gradually load applying over the road to check the settlement, this test is done with the help of vehicles.

I. Gradual load is applied by using vehicle over the surface of road.

II. Two-wheeler and four-wheeler vehicles with variation in load are used for the application of load. Following vehicles are to be tested over the road.

III. Avg. weight of moped = 104 kg. Avg. weight of bike = 111 kg.

IV. Weight of 4-wheeler = 650 to 1200 kg

Observation table: -

Sr. No.	WBM Road With Geocell Reinforced		
	Type of vehicle	**Weight of vehicle (kg)**	**Settlement (mm)**
1.	Pleasure	104	-
2.	CD Deluxe	111	-
3.	Alto 800	750	-

Observation table: -

Sr. No.	WBM Road Without Geocell Reinforced		
	Type of vehicle	Weight of vehicle (kg)	Settlement (mm)
1.	Pleasure	104	1
2.	CD Deluxe	111	1.5
3.	Alto 800	750	4

V.CONCLUSION

In conclusion, this research paper has explored the design and implementation of Water Bound Macadam (WBM) roads using geocell technology as a means to enhance their performance and durability. Through a comprehensive review of literature, analysis of design considerations, and examination of case studies, several key findings and conclusions have been drawn. Firstly, geocells offer a promising solution to address the challenges associated with traditional WBM roads, including poor load-bearing capacity, susceptibility to erosion, and deformation under traffic loads. By confining aggregate materials within a cellular matrix, geocells effectively distribute loads and improve the overall stability of the road base. Secondly, the design process for incorporating geocells into WBM road construction involves careful consideration of factors such as soil properties, traffic loading, and environmental conditions. Through geotechnical analysis and engineering principles, optimal geocell configurations can be determined to maximize the performance and longevity of the road. Furthermore, the implementation of geocell-reinforced WBM roads has been demonstrated to result in tangible benefits, including increased load-bearing capacity, reduced rutting, and enhanced resistance to erosion and moisture ingress. These improvements contribute to the overall durability and sustainability of the road infrastructure, leading to lower maintenance costs and extended service life.

VI.ACKNOWLEDGMENTS

We express our deepest gratitude to all those who have contributed to the completion of this research article on the design of 'WBM' road using Geocell technology. First and foremost, we extend our sincere appreciation to our supervisor, Prof. Rahul Dhanre, for their invaluable guidance, support, and encouragement throughout the research process. Their expertise and insights have been instrumental in shaping the direction and quality of this study. We would like to acknowledge the support of our colleagues and peers who provided valuable feedback and suggestions during the course of this research. Their constructive criticism and insightful discussions have greatly enriched the content of this article. We are also grateful to the participants of our study for their cooperation and willingness to share their experiences and insights. Without their contributions, this research would not have been possible. Furthermore, we would like to thank the funding agencies or organizations that supported this research financially. Their assistance enabled us to conduct the necessary experiments and analysis essential for this study.

REFERENCES

1. Strength and Rutting Characteristics of WBM with Partial Replacement of Aggregates by Steel Slag Vivek V Gavimath1 , Dr. Sureka Naagesh2 , Dr. H S Jagadeesh3 1 (PG Student, B M S College of Engineering, Bangalore, Karnataka, India) 2 (Professor, B M S College of Engineering, Bangalore, Karnataka, India) 3 (Professor, B M S College of Engineering, Bangalore, Karnataka, India) (year – 2017)
2. High-Modulus Geocells for Sustainable Highway Infrastructure Kief, O., Schary, Y., Pokharel, S.K., Dr. Ofer Kief, Senior Geotechnical Engineer; PRS, ofer@prs-med.com; Yitzchak Schary, MLA, Landscape Architect, PRS, yitzchak@prs-med.com Dr. Sanat Kumar Pokharel, Geotechnical Engineer, Stratum Logics, Canada, Sanat.Pokharel@stratumlogics.com
3. Strength and Rutting Characteristics of WBM with Partial Replacement of Aggregates by Steel Slag Vivek V Gavimath1 , Dr. Sureka Naagesh2 , Dr. H S Jagadeesh3 1 (PG Student, B M S College of Engineering, Bangalore, Karnataka, India) 2 (Professor, B M S College of Engineering, Bangalore, Karnataka, India) 3 (Professor, B M S College of Engineering, Bangalore, Karnataka, India (Jan . Feb. 2018)
4. International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 06 Issue: 01 | Jan 2019 www.irjet.net p-ISSN: 2395-0072

5. Republic of Iraq Ministry of Higher Education and Scientific Research University of Kerbala Civil Engineering of University of Kerbala ,(2014)
6. Journal of Analysis and Computation (JAC) (An International Peer Reviewed Journal), www.ijaconline.com, ISSN 0973-2861 National E-conference on "Research & Innovation, 2020
7. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X. PP 59-63 www.iosrjournals.org National Conference on Advances in Engineering, Technology & Management 59 | Page (AETM'15)" Geocell: An Emerging Technique Of Soil Reinforcement In Civil Engineering Field Gourav Dhane1 , Dhiraj Kumar2 , Akash priyadarshee3 1, 2, 3(Department of Civil Engineering, NIT Jalandhar, India)(2016)
8. Use of Geocell in Pavement Design: Final Report Technical Report 0-6833-1 Cooperative Research Program CENTER FOR TRANSPORTATION INFRASTRUCTURE SYSTEMS THE UNIVERSITY OF TEXAS AT EL PASO EL PASO, TX 79968 OHJOFFSJOHDUJT in cooperation with the Federal Highway Administration and the Texas Department of Transportation (Research Report 0-6833-1 November 2018 Published November 2021)
9. Use of Geocell in Pavement Design: Final Report Technical Report 0-6833-1 Cooperative Research Program CENTER FOR TRANSPORTATION INFRASTRUCTURE SYSTEMS THE UNIVERSITY OF TEXAS AT EL PASO EL PASO, TX 79968 OHJOFFSJOHDUJT in cooperation with the Federal Highway Administration and the Texas Department of Transportation (Research Report 0-6833-1 November 2018 Published November 2021)
10. Hemant Gulati, Dr. Devinder Sharma, Er. Neeraj Kumar, "Impact of roadway condition, traffic and manmade features on road safety," International journal of recent research aspects, ISSN: 2349-7688, pp. 1-5, Volume 4, Issue4, (December 2017)
11. Amanpreet guliani, Er. Neeraj kumar," study of existing highways and their capacity improvement", International research journal of engg & technology (IRJET), e-ISSN-2395-0056 P-ISSN-2395- 072, volume 5 Isssue 11 Nov 2018
12. Modelling and Analysis of Geocell Reinforced Foundations - Faby Mole P. AA Dissertation Submitted to Indian Institute of Technology Hyderabad in Partial Fulfillment of the Requirements for The Degree of Master of Technology/ Doctor of Philosophy (July 2013)
13. Experimental Studies on Geocells and Mat Systems for Stabilization of Unpaved Shoulders and Temporary Roads by Jun Guo Submitted to the graduate degree program in Civil, Environmental, and Architectural Engineering and the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Science. Date 12.02.2014

International Journal of Advanced Research in Arts, Science, Engineering & Management (IJARASEM)

| Mobile No: +91-9940572462 | Whatsapp: +91-9940572462 | ijarasem@gmail.com |

www.ijarasem.com