EVALUATION OF STATIC AND DYNAMIC PROPERTIES OF SAND REINFORCED WITH HUMAN HAIR FIBERS

RAGHVENDRA SAHU

DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI
MARCH 2018

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by

RAGHVENDRA SAHU

Department of Civil Engineering

Submitted

in fullfllment of the requirements of the degree of Doctor of Philosophy

to the

INDIAN INSTITUTE OF TECHNOLOGY DELHI

MARCH 2018

Dedicated to My Beloved Parents
Shri Ramesh Chandra Sahu and
Shrimati Laxmi Devi Sahu

CERTIFICATE

This is to certify that the thesis entitled **"EVALUATION OF STATIC AND DYNAMIC PROPERTIES OF SAND REINFORCED WITH HUMAN HAIR FIBERS"** submitted by **Mr. Raghvendra Sahu** to the Indian Institute of Technology Delhi, is a record of the bonafide research work carried out by him under our supervision and guidance. This thesis work, in our opinion, has reached the standard, fulfilling the requirements for **Doctor of Philosophy** degree. The research report and the results presented in this thesis have not been submitted, in part or full, to any other university or institute, for the award of any degree or diploma.

(Prof. G. V. Ramana)
Professor
Department of Civil Engineering
IIT Delhi, New Delhi-16
INDIA

(Prof. R. Ayothiraman)
Associate Professor
Department of Civil Engineering
IIT Delhi, New Delhi-16
INDIA

ACKNOWLEDGEMENTS

Completion of this doctoral dissertation has been possible with the support of several people. I would like to express my sincere gratitude to all of them. First of all, I am deeply indebted to my supervisors, **Prof. R. Ayothiraman,** Associate Professor and **Prof. G. V. Ramana**, Professor, Department of Civil Engineering, for their fundamental role in my doctoral work. I am extremely grateful to my supervisors, for their valuable guidance, scholarly inputs and consistent encouragement; I have been receiving throughout this research work. This feat was possible only because of the unconditional support provided by them. My supervisors have amicable and positive disposition, and always made themselves available in every aspect of work, despite their busy schedules. I consider it as a great opportunity to do my doctoral programme under their guidance and to learn from their research expertise. I would like to sincerely thank my supervisors for all kind of help and support.

The author expresses his gratitude to SRC: **Prof. B. J. Alappat (Chairman), Prof. Manoj Datta (Member)** and **Prof. M. K. Singha (Member)** for their valuable input at different stages of this thesis work, for improving the quality of the work.

I am thankful to **Prof. N. K. Garg**, Head of Civil Engineering Department, **Prof. A. K. Jain** and **Prof. Manoj Datta**, Former Heads of Civil Engineering Department and **Laboratory In-charge(s)**, Geotechnical Engineering Lab, for providing necessary space, fund, equipment etc. for conducting this research work.

I would like to sincerely thank the faculty members of Geotechnical Engineering Section: **Prof. K. G. Sharma, Prof. K. S. Rao, Prof. J. T. Shahu, Prof. B. Manna and Prof. Tanusree Chakraborty** for providing encouragement and suggestions.

I would like to thank **Prof. D. R. Sahoo**, Associate Professor of Civil Engineering Department who has been very kind enough to extend his help at various phases of my work, whenever I approached him.

This thesis would not have come to a successful completion, without the help that I received from **Prof. B. J. Ramaiah,** Visiting Faculty, Department of Civil Engineering, IIT Tirupati, related to cyclic triaxial tests and *SASW* testing. I would also like to thank **Mr. Aditya Singh** for his help in developing a MATLAB code which was used for data analysis. Special note of recognition and appreciation goes to them.

I extend my thanks to all geotechnical lab technician/staff: **Mr. Manoj Kumar Neelam**, **Mr. D. Biswas, Mr. Alok Kumar** and **Mr. D. S. Gusain (Retd.)**, **Mr. Munni Lal (Retd.)** for their kind help and support during the experimental work. I also acknowledge the help received from **Mr. Biri Singh**, and **Mr. Nitin Chaurasia**, Technicians, Structural Engineering Laboratories for their help in the experimental work. **Mr. Amit Bundela,** and **Mr. N. R. Gehlot,** for their help related to computational lab facilities.

Author would like to appreciate the Central Testing Facility and *SMITA* lab and Department of Chemistry of IIT Delhi for allowing us to test the soils and human hair fibers for their characterization.

Author would like to thank **Mr. Chandrasekhar** and **Mr. Mohit**, HBM India for extending their technical support for data acquisition system, whenever needed.

Author would like to thank **M/s Strata Geosystems (India) Pvt. Ltd**. for providing the geosynthetics material for experimental work carried out in this study.

I take this opportunity to thank my friends **Ankesh, Swapnil, Aditya, Baljeet, Tarun, Shilpi, P S Rao, Aali, Prateek, Endalu, Rebecca, Preeti, Tanwee, Sumeet Sir, A P Singh Sir, Amit Sir, Suresh Sir** and **Prasad sir** for their emotional support during the tough period of my research work.

I must thank **Mr. Dinesh, Mr. Shatrughan, Mr. Gopi** and **Mr. Ramjanm** for their hard work in preparation of sand bed for conducting the model and field experiments.

I owe a lot to my parents, who encouraged and helped me at every stage of my personal and academic life, and longed to see this achievement come true. I wants to thank my family members, who have shown faith in me. My wife **Reetu,** who has been with me all these years and has made them the best years of my life with her understanding and support. I thank my younger sisters **(Priyanka and Megha)** for their emotional support during the time of Ph.D. I thank my son, **Abhinav (Ishu)** who has been a source of patience, love and affection. His smile and innocent face made me forget the hardships during my research.

Above all, I owe it all to Almighty God for granting me the wisdom, health and strength to undertake this research task and enabling me to its completion.

Date: 15th March, 2018 **Raghvendra Sahu**

ABSTRACT

Machine foundations are designed such that the dynamic forces generated due to the operation of machines does not produce any type of adverse effects on the machine, foundation, operators and structures in close vicinity. When the block type machine foundation does not fulfil the design requirements, either piled foundation is usually provided or ground improvement techniques such as soil reinforcement can be adopted. The use of natural fibers as reinforcement is an economical alternative in place of commercial fibers. The present study investigates the effect of hair fiber (natural fiber) reinforcement on static and dynamic properties of sand.

Laboratory direct shear tests were conducted on unreinforced and hair fiber-reinforced sand under dry condition using unsorted hair fibers; under saturated condition, using both sorted (uniform length) and unsorted hair fibers. Results obtained for sand reinforced with sorted hair fibers were also compared with the results of sand reinforced with polypropylene fibers. The shear stress and volume change behavior measured during direct shear testing were quantified to assess the influence of (i) amount of fiber content and (ii) fiber length. Results indicated that (i) strength parameters increased substantially under dry condition, (ii) increase in strength parameters under saturated condition are observed to be insignificant and (iii) unsorted hair fibers as collected from barber shops can be effectively used as reinforcing elements.

Drained cyclic triaxial tests were conducted on sand reinforced with unsorted hair fibers. Measured shear modulus and damping characteristics were compared with unreinforced sand. Variation of shear modulus and damping ratio with shear strain were developed for sand reinforced with hair fibers up to 1% by dry weight. Shear modulus of sand reinforced with hair fibers exhibited an increase in modulus up to medium strains and damping characteristics marginally reduced compared to unreinforced sand.

Free vibration tests were carried out on model foundation resting on unreinforced and reinforced sand using three different reinforcing materials i.e. human hair fiber (HHF), PET geogrid and HDPE geogrid. The effect of lateral and vertical extent of reinforcement was also investigated using different reinforcement configurations. The data was interpreted to quantify the optimum reinforcement parameters for improving the dynamic properties of sand-foundation system. The results on different reinforcement configuration indicated that the zone of reinforcement equal to the plan dimensions of footing is adequate to shift the natural frequency of sand-foundation system. Damping measured from the model tests was found to be less for reinforced ground as observed from cyclic triaxial test results.

In-situ block vibration tests were conducted to determine the dynamic characteristics of soil-foundation system. Additionally, influence of geocell reinforcement below the foundation was also investigated. The results were interpreted to quantify the effect of reinforcement on shifting the natural frequency and change in amplitude of soil-foundation system. As observed in the model tests, results of field tests confirmed a shift in natural frequency and a reduction in damping characteristics.

Application and economic benefits of hair fiber reinforcement in select geotechnical problems (Retaining wall and machine foundations) were demonstrated.

सार

मशीन नींव इस तरह तैयार किए जाते हैं कि मशीनों के संचालन के कारण उत्पन्न गतिशील बल मशीनों, फाउंडेशन, ऑपरेटर और करीबी नजदीकी संरचनाओं पर किसी प्रकार के प्रतिकूल प्रभाव उत्पन्न नहीं करते हैं। जब ब्लॉक टाइप मशीन नींव डिजाइन आवश्यकताओं को पूरा नहीं करता है, तो या तो पाइल नींव आमतौर पर प्रदान की जाती है या जमीन सुधार तकनीकों जैसे कि मिट्टी सुदृढीकरण को अपनाया जा सकता है। सुदृढीकरण के रूप में प्राकृतिक फाइबर का उपयोग व्यावसायिक फाइबर के स्थान पर एक आर्थिक विकल्प है। वर्तमान अध्ययन रेत के स्थिर और गतिशील गुणों पर बाल फाइबर (प्राकृतिक फाइबर) सुदृढीकरण के प्रभाव की जांच करता है।

बिना प्रयोग किए गए बाल तंतुओं का उपयोग करके सूखी हालत के तहत गैर-प्रबलित और बाल फाइबर प्रबलित रेत पर संतृप्त स्थिति के तहत, सॉर्ट किए गए दोनों, वर्दी लंबाई और रिक्त बाल तंतुओं का उपयोग कर प्रयोगशाला प्रत्यक्ष कतरनी परीक्षण किया गया। छांटे हुए बालों के फाइबर के साथ प्रबलित रेत के लिए प्राप्त परिणामों को भी पॉलीप्रोपीलीन फाइबर के साथ प्रबलित रेत के परिणाम के साथ तुलना किया गया। (i) फाइबर सामग्री की मात्रा और (ii) फाइबर लम्बाई के प्रभाव का आकलन करने के लिए, प्रत्यक्ष कतरनी परीक्षण के दौरान मापा गया कतरनी तनाव और आयतन परिवर्तन के व्यवहार की मात्रा निर्धारित की गयी। परिणाम से संकेत मिलता है कि (i) सूखी हालत के तहत ताकत मापदंडों में काफी वृद्धि हुई है, (ii) संतृप्त अवस्था के तहत ताकत मापदंडों में वृद्धि को तुच्छ माना जाता है और (iii) नाई की दुकानों से एकत्र किए गए बिना व्यवस्थित बाल तंतुओं को प्रभावी ढंग से प्रबल करने वाले तत्वों के रूप में इस्तेमाल किया जा सकता है।

अनियंत्रित बाल तंतुओं के साथ सुदृढ़ रेत पर रेखीय चक्रीय त्रिकोणीय परीक्षण किया गया। बालों के फाइबर प्रबलित रेत के कतरनी मापांक और अवमन्दक विशेषताओं की गैर-प्रबलित

रेत के साथ तुलना की गई थी। कतरनी मापांक और अवमन्दक अनुपात में भिन्नता, कतरनी तनाव के साथ, 1% बाल फाइबर (सूखी वजन) प्रबलित रेत के लिए विकसित किया गया। बालों के फाइबर के साथ प्रबलित रेत के कतरन मापांक ने मापांक में मध्यम उपभेदों में वृद्धि की है और अवमन्दक विशेषताओं को गैर-प्रबलित रेत की तुलना में कम कर दिया।

गैर-प्रबलित और प्रबलित रेत पर तीन अलग-अलग रीनिफोर्सिंग सामग्रियों का प्रयोग करते हुए मॉडल फाउंडेशन पर स्वतंत्र कंपन परीक्षण किये गये, अर्थात मानव बाल फाइबर (एचएचएफ), पीईटी जियोग्रिड और एचडीपीई जीओजीड सुदृढीकरण की पार्श्व और ऊर्ध्वाधर सीमा का प्रभाव भी विभिन्न सुदृढीकरण विन्यासों का उपयोग करके जांच की गई। रेत-नींव प्रणाली के गतिशील गुणों में सुधार के लिए इष्टतम सुदृढीकरण मापदंडों को मापने के लिए डेटा की व्याख्या की गई थी। विभिन्न सुदृढीकरण विन्यास के परिणामों ने संकेत दिया कि रेत-नींव प्रणाली की प्राकृतिक आवृत्ति को स्थानांतरित करने के लिए फुटिंग के प्लान आयाम के बराबर सुदृढीकरण का क्षेत्र पर्याप्त है। चक्रीय त्रिकोणीय परीक्षण के परिणाम से मनाया गया कि मॉडल टेस्ट से मापा अवमन्दक, प्रबलित जमीन के लिए कम पाया गया था।

मृदा-नींव प्रणाली की गतिशील विशेषताओं को निर्धारित करने के लिए इन-सितु ब्लॉक कंपन परीक्षण आयोजित किए गए थे। इसके अतिरिक्त, नींव के नीचे जियोसेल सुदृढीकरण के प्रभाव की जांच भी की गई। परिणामों को प्राकृतिक आवृत्ति और मिट्टी-नींव प्रणाली के आयाम में परिवर्तन को बदलने पर सुदृढीकरण के प्रभाव का अनुमान लगाने के लिए व्याख्या की गई। जैसा कि मॉडल परीक्षणों में देखा गया है, क्षेत्र परीक्षणों के परिणाम ने प्राकृतिक आवृत्ति में बदलाव और अवमन्दक विशेषताओं में कमी की पुष्टि की है

चयनित भू-तकनीकी समस्याओं (बनाए रखने की दीवार और मशीन नींव) में बाल फाइबर सुदृढीकरण के अनुप्रयोग और आर्थिक लाभ का प्रदर्शन किया गया।

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