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DEVELOPMENT OF 3D CONCRETE PRODUCTION TECHNOLOGY FOR APPLICATION OF ROAD CONSTRUCTION

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ABSTRACT

This study introduces the development of new technology that uses 3-dimensional (3D) wire mesh as the reinforcement for 3D concrete pavement. A process for new 3D concrete pavement production including manufacturing, assembling, and cement pouring was proposed. Methods to mathematically calculate the load capacity of the slabs were also given in detail. The results exhibited an enhancement in load capacity of the as-prepared 3D concrete pavement by 1.3 – 2.1 times as compared with that of the plain one.

Keywords:
3-dimensional wire mesh, 3D concrete pavements, road construction, load capacity.

INTRODUCTION

In recent years, concrete has been commonly used in the construction of many road works. However, because of the poor tensile and bending ability, temperature fluctuation, and other overload factors, the concrete structure is often cracked, broken, or damaged during use. The solutions to increase the load capacity include increasing the pavement thickness, the concrete grade, treating the road well, etc. Nonetheless, due to the limit of conventional techniques, the enhancement was unremarkable. Therefore, it is necessary to develop new technology to overcome these difficulties. Since the creation of a model using the wire mesh reinforcement for concrete pavements, the load capacity of that system was comparably improved [1]. Later, the applications of that idea for civil construction hooked many scientists up [2-6]. However, because the used system was not a three-dimensional structure, the efficiency increased insufficiently. In Vietnam, many engineers and scientists also proposed solutions to overcome these issues [7-13]. Thus, this work contributes some research results related to the development of 3D wire mesh technology as reinforcement for 3D concrete pavement and attempt at road construction and other transportation structures in Vietnam.

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EXPERIMENTAL

Materials and Equipment

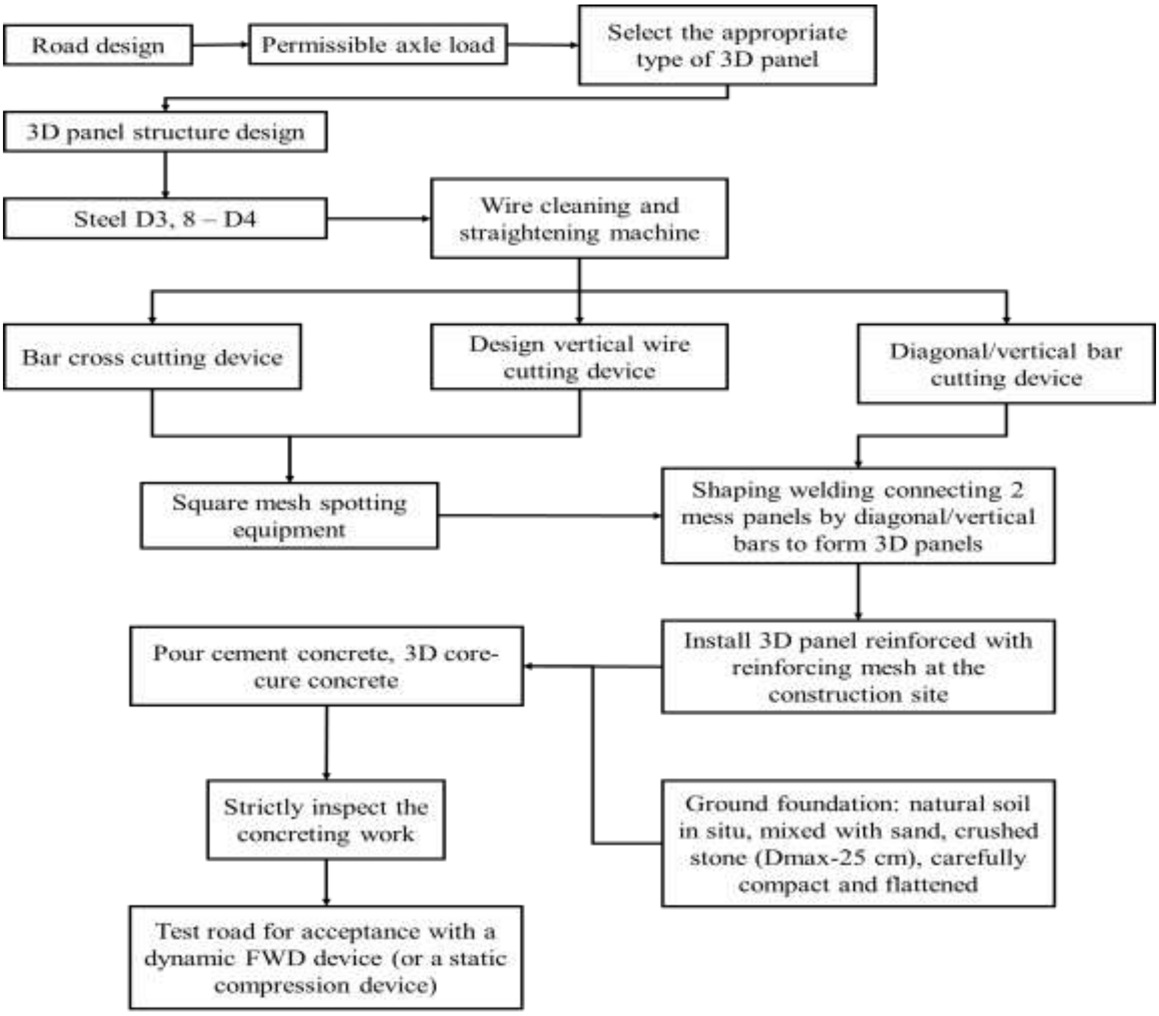
All equipment including tractors, cleaning machines, straightening machines, wire cutting machines, steel wire flattening machines, wire mesh flattening machine, wire mesh cutting machine, spot welding machine system, and fixing frame systems, and all materials involving steel, cement, stones, sand, water, etc., were purchased from domestic companies and used without further modification.

Experimental

The production process of 3D concrete pavements was proposed and developed following Scheme 1. The pictures captured at the field when fabricating the 3D wire mesh panels are also displayed in Fig. 1.

Software and calculation methods

Software including MICROSOFT EXCEL, SOLIDWORKS, ANSYS ABAQUS, etc. was utilized to design, calculate, and simulate numerically 3D concrete panels reinforced with wire mesh. FWD dynamic load and the destructive static compression device were employed to measure the parameters of 3D concrete panels in the field.



Scheme 1: Proposed process for designing, constructing, and testing of 3D wire mesh concrete pavement

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Fig. 1: Actual photos taken in the field: A, B, C. Installation of 3D wire mesh panels; D. 3D slab concrete pouring; E. Testing for load assessment by FWD device; F, G. Testing of destructive compression to determine calculation data.

RESULTS AND DISCUSSION

3D wire mesh panel structure

Based on the literature review and realistic investigation, a 3D wire mesh structure has been designed and obtained for different purposes.

For embankments, drainage ditches, roadside anti-erosion works or roadsides with small axial load of under 12 tons, it is allowed to use a 5 cm-thick reinforced core and 10 cm-thick concrete with the following structure (Fig. 2).

For road construction, the pavement has no foam layer between the two wire mesh panels. In addition, the pavement uses a cold drawn steel with Φ3.8 – 4 mm to spot square meshes, diagonal bars, and vertical bars. The pavement utilized more vertical bars and diagonal bars with a total of 440 bars/m2 (Fig. 3)

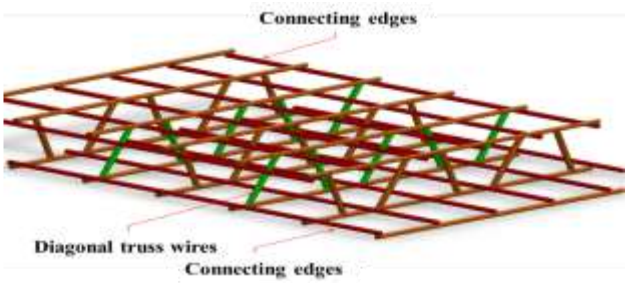

Fig 2: A 3D wire mesh panel structure

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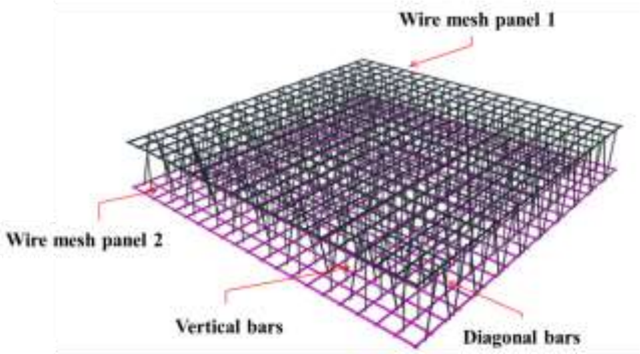

Fig. 3: A 3D wire mesh structure with 440 bars/m^2.

Structural analyses of prepared metallic nutrients

During the research, the authors used the control comparative method between plain concrete and 3D concrete panels by fabricating 150 samples of plain concrete and 3D concrete panels in experiments measuring compressive and tensile strength. From the measurement and calculation results, a comparison of strength between plain concrete and 3D concrete is demonstrated in Table 1.

Table 1. *Comparison of compressive and tensile strength between plain concrete and 3D concretes*

Compressive strength of the structure of 220 diagonal bars/m^2	**Tensile strength in bending of the structure of 220 diagonal bars/m^2**	**Tensile strength in bending of the structure of 440 diagonal and vertical bars/m^2**
- Compressive strength increases from 5 - 15% when the 3D wire mesh is available, and increases more highly when the panel thickness reduces: The increase of thin panels is more obvious. - Compressive strength increases more strongly when the concrete grade is higher, especially for panel thicknesses of 10cm and 15cm.	- 10cm-thick panel: $R_{ku3D}{}^{tk} = 2.07\ R_{ku}{}^{tk}$ - 15cm-thick panel: $R_{ku3D}{}^{tk} = 1.70\ R_{ku}{}^{tk}$ - 20cm-thick panel: $R_{ku3D}{}^{tk} = 1.30\ R_{ku}{}^{tk}$	- 10cm-thick panel: $R_{ku3D}{}^{tk} = 2.14\ R_{ku}$ - 15cm-thick panel: $R_{ku3D}{}^{tk} = 1.88\ R_{ku}$ - 20cm-thick panel: $R_{ku3D}{}^{tk} = 1.78\ R_{ku}$ - 25cm-thick panel: $R_{ku3D}{}^{tk} = 1.51\ R_{ku}$

Thus, the tensile and flexural strength of the 3D concrete samples with 440 diagonal bars and vertical bars sample as a control increased by 1.50 – 2.14 times as compared with the plain concretes.

Comparison of roadbed treatment using 3D concrete and plain concrete in a typical road in Vietnam

In Vietnam, the treatment of roadbeds on traffic routes in soft soils in erratic rainy weather is relatively complicated. Because the rainy season often lasts for hours per day in consecutive months, the treatment of the roadbed with concrete often encounters many difficulties. Rainwater makes the roadbed wet and changes the percentages of the components in the cement, which weaken the concrete strength and structure. Therefore, the required time for the pre-treatment and accomplishment of concrete roads in those areas is usually prolonged or postponed for months.

This work has tested and verified the superiority of 3D concrete reinforced with wire mesh for road construction. When employing this technology, the treatment of the roadbed is simpler and faster than that of the plain ones. On the other hand, 3D concrete technology reinforced with wire mesh is especially suitable for road construction in places with soft soils and unstable weather, which does not allow for long-term construction.

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Table 2. *Comparison of roadbed treatment using 3D concrete and plain concrete in Phong My Ward, Phong Dien District, Thua Thien Hue Province*

Step	For plain concrete following Vietnam Standards	For 3D concrete (from panels 2-9)	For 3D concrete (panel 1)
1	Excavate the entire 1.0 – 5.0 m missing rock layer depending on the terrain, soft soil	Remove grass on the ground	Remove grass on the ground
2	Backfill and compact up to K95	No Step 2	Mix up the soil and reinforced the road with chemical RRP235 + 4% lime, thoroughly compact and flatten it to a thickness of about 20 cm.
3	Compact tightly so that the upper layer reaches K98	No Step 3	No Step 3
4	Pour 1 layer of crushed stone, and sand (base), then compact with a thickness of about 25 cm	Pour 1 layer of 2.0 – 6.5 cm crushed stone with a thickness of 20 cm and then compact thoroughly to flatten, the top is a layer of crushed stone, sand to create a flat surface with a thickness of about 1.0 – 2.0 cm.	Pour 1 layer of crushed stone, sand, and compact to create a flat surface with a thickness of about 1.0 – 2.0 cm
5	Pour concrete with a thickness of 25 cm, grade 300	Pour 3D concrete M300	Pour 3D concrete M300

The average load capacity of 3D concrete panels and plain concrete panels

According to the obtained results in Table 3, the concrete panels using 3D steel mesh displayed an increase in the load capacity by 1.5 – 2.1 times under the same ground conditions. In addition, the advantages of concrete panels on the soft ground were further bolded by compared with the permission load of 25-cm-thick plain concrete panels treated following the the national standards (Table 4). Although the roadbed has been excavated in depth and constructed according to the Vietnamese standards, the permissible load is still much lower than the roads constructed with 3D concrete panels with thickness of 20 cm on soft ground.

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Table 3. The average load capacity of 3D concrete panels and plain concrete panels (measured by the FWD method)

No.	Type	Permissible load (kg)	Compression
	25cm thick panel		
1	3D concrete panel 2 at a compression of 199.44 kN	33 622.970	At compression of 100 tons, the concrete is not crushed
2	Plain concrete panel 3 at a compression of 200.09kN	22 877.24	Crushed at a compression of 40 tons
	20cm thick panel		
3	3D concrete panel 1 at a compression of 199.77 kN	27 804.36	At compression of 100 tons, the concrete is not crushed
4	3D concrete panel 4 at a compression of 199.91kN	31 253.73	At compression of 100 tons, the concrete is not crushed
5	Plain concrete panel 5 at compression of 199.34kN	15 623.98	Crushed at a compression of 35 tons
	15cm thick panel		
6	3D concrete panel 6 at a compression of 198.61kN	17 981.98	At compression of 60 tons, the concrete is not crushed
7	Plain concrete panel 7 at a compression of 198.75kN	9 181.61	Crushed at a compression of 25 tons
	10cm thick panel		
8	3D concrete panel 8 at a compression of 199.195kN	12 759.81	At compression of 45 tons, the concrete is not crushed
9	3D concrete panel 9 at a compression of 195.64 kN	5 133.14	Crushed at a compression of 15 tons

Table 4. *The permission load of some 25-cm-thich plain concrete panels treated following the National Standards of Vietnam*

Panel	Permissible load (FWD) (kg)
1	22 462.611
2	19 897.513
3	21 142.302
Average	**21 167.475**

CONCLUSION

❖ The production process of new 3D concrete pavements was proposed and successfully developed.
❖ The two methods of measurement by FWD and static compression give similar results for both ordinary and 3D concrete panels.
❖ The load capacity of 3D concrete pavement was enhanced by 1.5 to 2.1 times as compared to plain concrete pavement. With the current situation of overloaded vehicles in Vietnam, it is difficult to destroy the pavement.
❖ With the new technology, some preliminary treatment steps for road construction were deducted without reducing the quality of road and concrete panels. Hence, the budget for road construction can be decreased.

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