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INNOVATIVE MICRO-DUST REDUCTION TECHNOLOGIES

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ABSTRACT

Background: An optimum design of road facilities, such as cantilever columns for traffic lights, walkway block for the purpose of rainwater harvesting with the development of an integration of pole with foundation of street lights on highways is proposed for solving current significant challenges of air pollution. In this study, we suggested solutions for given problems by determination for the location of minimum principal stress in walkway blocks against moving foot loads to design and verifying the determined location of minimum principal stress. Method: An optimum design with a verification example for determined location of minimum principal stress have been presented in a two-dimensional Block member on elastic foundation for pedestrian walkway for reserving water inside. Results: The minimum value for sum of shear forces is found when x1 is 58.58 mm (30% of total span, 200mm), while the minimum deformation is located at x2 = 80 mm (70% of total span, 200mm). In a modified model, when moving boundary condition (walkway foot loads) is located at x1 = 0 mm), the location of minimum principal stresses is found at 168 mm (84% of span, 200mm), in which the stress concentration due to the foot load is modelled as two layers of distributed loads (reactions of foundation modelled as springs). Conclusion: Consequently, zero deformed reservoirs for rainwater on the neutral axis (x2 = 167mm) has been determined in the modified model with three-dimensional FEM analysis verifications.

KEYWORDS

minimum principal stress, walkway block

1.INTRODUCTION

Two invisible killers, micro dust little than 10 micro meters (PM 10) and little than 2.5 micro meters (PM 2.5) could infiltrate into the lung of human, resulting various types of illness. Referring to a latest research, when the density of PM2.5 increases $5\mu m/~3$, the probability of lung cancer increases up to 18 %, while PM10 increases $10\mu m/~3$, the probability of lung cancer increases up to 22 % [1]. Consequently, millions of humans are dying due to those two destroyers.

If focused on reducing air pollution, there are two ways of solutions: dry and wet methods. Dry solution generally uses electric dust collection machines while wet one uses water spraying in most cases [2,3,4].

Based on recent comparison of the two methods, more results show wet method as effective 11.7%, as illustrated in Table 1. The best recommended solution is using the two ways at the same time [3].

When applied solely, the effects of reduced micro-dust in the air was approximately 10 to 30%, while it can be increased to 50% if applied two methods simultaneously.

The authors have proposed solutions for the above problems via submitting patent documents, composed of harvesting rainwater, producing automatic power supplying from clockwork spring, and water spraying pump without clogging in 4 seasons continuously, which is illustrated in Figure 1 and Figure 2. The proposed solutions in the Figure 1 and Figure 2 might be possible to solve the above problems because we will upgrade our road facilities from street light pole to "water spraying system" at the same time [5].

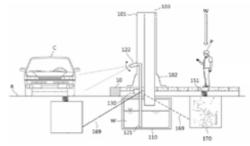


Figure 1: Water Spraying System

Trees are natural carbon eaters. All plants need CO_2 to complete their life cycle. Trees digest CO_2 , remove and store carbon while delivering O_2 back into the air. Due to this characteristic, it's a good option of climate change mitigation. Trees are more efficient in carbon sinking process while plants do less. Pine trees are best carbon absorbers [12]. In one year, an acre of mature trees absorbs the amount of CO_2 produced which a car drive CO_2 produced which

2. DETAIL METHODOLOGIES

2.1 The current rainwater harvesting in Korea

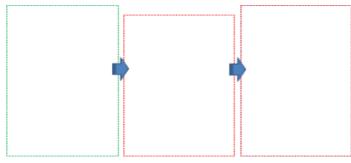


Figure 3: Process of Development for water spraying

As a part of the proposed system by authors, rainwater harvesting walkway block has various types of form as follows:

- 1) Two-part blocks with increased parallel water flow, in which flow rate can be controlled due to its tilted connection (Figure 3(a))
- Two-part folded blocks with decreased distributed reactions to lower part, in which part of the external forces may flow to folded part, resulting larger volume for reserving rainwater (Figure 3(b))

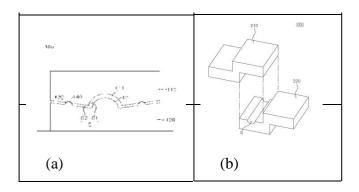


Figure 3: Schematic design of rainwater harvesting blocks in several forms (proposed patents) [5].

Porous walkway blocks are constructed for the purpose already, but in the conventional one, reserved water is easily consumed due to the bigger permeability than necessary [6]. Furthermore, porous structure reduces the strength of blocks, which resulting cracking and settlements in walkways. Therefore, we may need to establish solutions for the following essential questions:

- Do we have definite directions for appropriate usage of harvested rainwater;
- 2) will there be enough water resources for our needs?
- 1. Storage and more 2 without. Automatic execution electronical power 3. Spraying under car

1.1on top and side of Guide of rainwater 2.1block or Under walk road 3.1 spaying (122) to under High pressure column and back side of cars 2.2 Under road to reduce micro-dust 1.2 Reserve water clockwork (springinside of foundation upto 5kNdeformation energy storage device (Figure

4)3.2 3located nozzles or 4 parallel considering clogging 1.3from inside of road Additional water 2.3 energy stored in Deformation 3.3 optimum design blocks, connected to clockwork due to of nozzle: two kinds clockwork (spring rotation will trigger of different stainless energy generation piston-pump (130), steel having different device) water (Figure. upto3)10 kN of thus spraying thermalexpansioncoefficient, 2.4 Design: nozzle size considering winter and stiffness of spring temperature

We could develop a practical artificial tree, 1) providing enough water resources for our needs, 2) solving current environmental needs, which are described more, of air pollution in Mega cities, and 3)investing minimum cost for the above 1) and 2).

It might be possible through the suggested walkway blocks for rain water harvesting for reducing micro dusts near road area, discussed more in subsequent sections [7].

1) Solving current environmental needs of airpollution in Mega cities, and 3) investingminimum cost for the above 1) and securingreliable safety at the same time. Whileraining it is not necessary to spray water. Therefore, we need to control the water leveland time to spray based on the height of reserved water. It is possible to use the open patent for the problem, in which the closer of providing water to pump (4) is controlled by buoyancy dependent plate (2). When the height of water level is higher than criteria of raining, the connection part (3) is closed due to the movement of plate (2) connected to vacant tank, moving by buoyancy.

2.2 Objectives and scope

As presented in backgrounds, the suggested structure is a part of the proposed preventing air pollution system [8]. The rainwater harvesting walkway block on elastic foundation shown in the Fig. 3 would contact adjacent blocks and deformed against external loads. To design void volume in the blocks at the location of minimum principal stress, this study focused on the following research objectives.

- 1) Determination for the location of minimum principal stress in walkway blocks against moving foot loads
- Design and verification for determined location of minimum principal stress

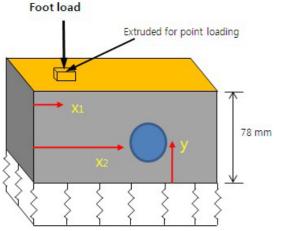


Figure 4: Brick on elastic foundation in pedestrian walkway for reserving water inside

As a pilot study, allowable stress design method is applied in this research [9]. Material for blocks and foundation follows linear elastic behaviour in their constitutive relationship Simplified model is selected for two dimensional models for optimum design of minimum principal stress with unit thickness in their width Three-dimensional finite element models are applied for verifying the results of two dimensional designs [10]. Full scale experiments might be out of scope in this research.

2.3 Location of moving foot load case I

The walkway blocks are located on elastic foundation. One block may be contacted with adjacent blocks under external loads, which is considered as a hinge boundary condition in the model. Higher order indeterminacy is remaining due to the number of springs, for modelling ofe lastic foundations. Hence, in the two-dimensional simplified model, the considered system is reversed 1800 for z axis presented in Figure 5, in which

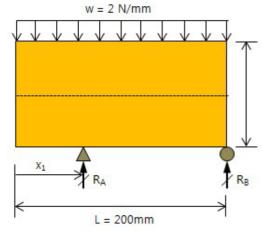


Figure 5: Model for block member on elastic foundation via reversing

In this case, the shear forces from 0 to x1 and from x1 to x2 are:

$$V_{x} = -\omega \cdot x$$

(1) $V_{x} = -\omega \cdot x_1 + R_{x} - \omega \cdot x_2$ (2) Where, x2 is the length from the point A to the location of maximum bending moment, and reactions in Figure. 5 can be derived from:

The bending moments due to moving load from 0 to x1 and x1 to x2 are:

$$M_{\chi} = \frac{-\omega \cdot \chi^2}{2} \tag{3}$$

$$M_{x2} = R \cdot x_2 - \frac{\omega \cdot (x_1 + x_2)^2}{2}$$

$$R_{x1} = \frac{\frac{\omega \cdot L^2}{2}}{L - x}$$
(4)

$$R_{x1} = \frac{2}{L-x} \tag{5}$$

2.4 Location of moving foot load case II

The exact response of spring may show stress concentration as a function of length, stiffness, and impact of the dynamically moving foot loads. Therefore, the CASE I model with evenly distributed reactions (loads in the model) may have difference in the site. The stress concentration (reactions and spring stiffness) effect has been modeled in CASE II, shown in Figure. 5.

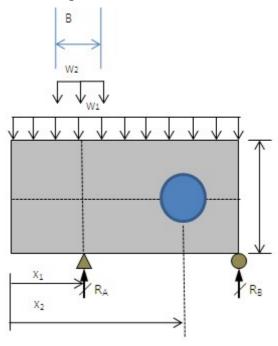


Figure 6: Reversed brick model on elastic in pedestrian walkway for reserving water inside

In this case, added variables are other distributed loads (w2) with width of B. The shear forces from 0 to x1 and from x1 to x2 will be:

$$V \times 2 = -\omega \times 1 + R \times 1 - \omega \times 2 - \omega_2 \cdot B; 0 \le x \le x$$
 (7)

Where, x2 is the length from the point A to the location of maximum bending moment, and reactions in Fig. 6 can be derived from: The bending moments due to moving load from 0 to x1 and x1 to x2 are:

$$M_{x} = \frac{-\omega \cdot x^{2}}{2} - \frac{-\omega \cdot 25x^{2}}{2}$$

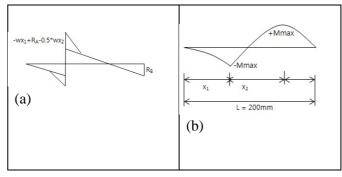
$$Mx2 = R \cdot x_{2} - \frac{-\omega \cdot B}{2} - \omega_{2} \cdot B \cdot \omega \cdot (x + 2)^{2}$$
(8)

 $\boldsymbol{\chi}_2$

(9)

$$R_x = \frac{\omega}{\frac{2}{L-x}} + \omega_2 \cdot B \tag{10}$$

The shear force and bending moment diagram would be like the Figure 7



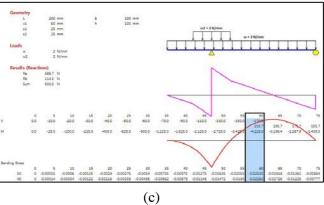


Figure 7: (a) Shear force diagram, (b) Bending moment diagram due to walking load on rain water harvesting block located on an elastic foundation.

As presented in Figure 7(a), in the rainwater harvesting blocks assumed as a simply supported beam, the moving boundary condition act as a reaction (in fact, which is a moving live load), producing maximum shear forces at just left and right of the location of loading [11]. Other reactions at the right end of the span may need to be compared with the maximum values (x1 in the Figure). In Figure 7(b), the maximum bending moments are located at the point of loading and at some point (x2 in the Figure) right side of the loading, which are negative and positive moments respectively. If x1 is determined, x2 can be calculated. However, moving load can make any arbitrary location for x1. Therefore, to determine the location of x1, 1) modelling probabilistic distribution for x1, or 2) considering many points as "a x1" as many locations as much, which can make meaningless results, if there be very little difference between maximum and minimum stress or strains compared for every moving load cases [12,13]. The probabilistic distribution model may need many cases of loads as well, even though we have rather acceptably appropriate distribution. Consequently, we have designed an intentionally determined location of moving loading by extruding some part of the surface of the blocks, in which the location of extrusion has been determined based on an optimum design considering minimum values for maximum shear forces and bending moments evaluated by equation from (1) to (4).

2.5 Minimizing principal stress by an optimization for the location of moving load, for CASE I

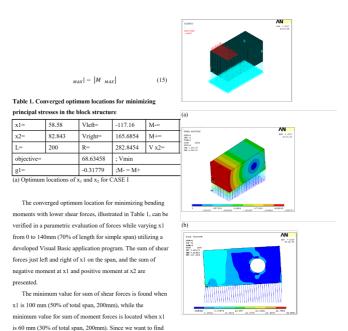
The design optimization is applied per generalized reduced dimensional gradient method, GRG (Generalized Reduced Gradient Method) [13]. GRG design methods are equivalent constraints limit conditions in a way that to obtain to solve the minimization problem currently active constraints on remaining variables after clearing the dependent variable as the processes to be always active, even after improvement [14].

Convex simplex method and the GRG algorithm are approximation methods that are similar in spirit to the Simplex method for LP. The reduced gradient method and the CSM operate on a linear constraint set with nonnegative decision variables, while GRG generalizes the procedure to nonlinear constraints, possibly with lower and upper bounds on decision variables [15]. Therefore, GRG is essentially a generalization of the convex simplex method to solve for minimizing volume of the foundation: Min f(x) = Sum of just left and right of shearforces at the

location of load

Subject to
$$gj(x)=0, j=1, 2, ..., m$$
 ai ϵ $xi < b 1, i=1,2,...,n;$ xi R^n .

Compared with SIMPLEX method, GRG method use reduced gradients]instead of Creduced costs. Independent variables need not be at their bounds in GRG method and could be changed their values in each]iterative evalua tion [16]. HIt would be hard to make every limit state functions to convex problem. Henc e Cthe alternative could be run repeatedly, a multiple starting of GRG optimization, which makes it evade local minima. The process of anW automatically chosen multiple starting values for the decision variables may find a better solution [17].



Since there is about 10 times difference in their magnitude between shear stress and bending stress, difference of shear forces just left and right under the external load are selected as the objective function, while the difference of bending moments in their negative and positive maximum values is utilized as a constraint as follows:

Min f(x) = Sum of just left and right of shear forces at the location of load

Subject to
$$g(x)=|M^-|$$

the location of minimum principal stresses, the target location

might be around 60mm when the sum of moment forces are

minimum value, which was the constraints function in the design optimization, minimizing sum of shear forces at the location of load.

2.5 Comparison with Finite Element Analysis

Figure 8: (a) Load, boundary conditions and reactions for the target structure, (b) Principal stresses of the walkway block (C) Nodal deformation in plane stress model

In the verification analysis via ANSYS finite element analysis, the proposed walkway block showed very close deformation with the analytical derivations presented in previous sections shown in Figure 7.

3. CONCLUSIONS

To solve current challenges of air pollution near road side, five patents have been submitted to compose the automatic water spraying system, working four seasons without external electric power at all. To supply enough water to the spraying system, we are suggesting rainwater harvesting from the water on walkways.

The proposed walkway blocks drilled in their body for rainwater harvesting is optimally designed and validated as a preliminary evaluation of a design, which overcomes the current porous blocks which shows cracking, settlements and degradation under external loads due to the bigger permeability than necessary. Random variable of location of moving load is assumed as a fixed point responses while varying the dimension of void from 5 to 60 mm in their diameter. However, the difference of stress and deformation is larger than 20% compared with the case, which has a void under the load.

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