Lecture Notes in Civil Engineering

Elham Maghsoudi Nia
Mokhtar Awang *Editors*

Advances in Civil Engineering Materials

Selected Articles from the 7th International Conference on Architecture and Civil Engineering (ICACE 2023), Putrajaya, Malaysia

Springer

Lecture Notes in Civil Engineering

Volume 466

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ISSN 2366-2557 ISSN 2366-2565 (electronic)
Lecture Notes in Civil Engineering
ISBN 978-981-97-0750-8 ISBN 978-981-97-0751-5 (eBook)
https://doi.org/10.1007/978-981-97-0751-5

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Preface

We are delighted to present this compilation of selected papers from the 7th International Conference on Architecture and Civil Engineering (ICACE 2023). This conference brought together leading experts, researchers, and practitioners from around the world to share their insights and advancements in the fields of architecture and civil engineering.

The papers featured in this volume encompass a broad spectrum of topics, reflecting the diverse and evolving nature of these disciplines. From innovative materials and cutting-edge simulation techniques to sustainable energy solutions, efficient traffic management, and a nuanced understanding of human behavior in construction management, the contributions presented here represent the forefront of contemporary research and development.

As the global community faces unprecedented challenges in the fields of urbanization, infrastructure development, and environmental sustainability, the importance of collaborative efforts and interdisciplinary approaches cannot be overstated. The ICACE 2023 conference provided a unique platform for scholars and professionals to exchange ideas, foster collaborations, and address the pressing issues that shape the future of architecture and civil engineering.

This compilation serves as a testament to the collective intellect and dedication of the authors whose work is showcased within these pages. Their commitment to advancing knowledge and driving innovation in the field is commendable, and we are grateful for their valuable contributions.

We extend our sincere gratitude to all authors, reviewers, and conference session chairs who have played an important role in the success of ICACE 2023. It is our hope that this book will serve as a valuable resource for researchers, engineering practitioners, as well as students, inspiring further exploration and advancements in the ever-evolving domains of architecture and civil engineering.

Delft, The Netherlands — Elham Maghsoudi Nia
Seri Iskander, Malaysia — Mokhtar Awang

Contents

Crack's Influence on the Vibration Control Ability of Mass Concrete Layer

Zhang Jian, Li Xiangdong, Wang Yuchuan, Zheng Ming, Nie Xin, Fan Jiansheng, and Liu Yufei

Abstract Mass concrete layer is one of the most effective methods to control ground vibration in high-precision facilities. Since it is inevitable for the appearance of the crack in mass concrete layer, this paper presents a numerical simulation to investigate the crack's influence on the vibration control ability of a mass concrete in the frequency band of 1–100 Hz. The numerical simulation is based on a simplified finite element model. The simulation results indicate that increasing thickness improves the vibration control ability of the concreter layer. The crack parallel to the vibration propagation direction amplifies the vibration velocities obtained near the crack, and the crack perpendicular to the vibration propagation direction amplifies the vibration velocities obtained between the crack and vibration source. Moreover, the first crack on the concrete layer puts the most significant influence on the vibration control ability of the concrete layer.

Keywords Passive vibration control · Finite element model · Mass concrete layer · Cracks in concrete layer

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E. M. Nia and M. Awang (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 466, https://doi.org/10.1007/978-981-97-0751-5_1

1 Introduction

High-precision facilities, such as electron microscopes, synchrotron radiation sources, electronic industrial buildings, and precision lathes, are important facilities to advance modern technology. During operation, such facilities are highly sensitive to the ground vibration which is an assembly of natural phenomena (remote earthquake, sea wave washing shores, etc.) and human activities (heavy traffic, air conditioner operation, etc.) [1, 2]. To control the influence of the ground vibration, various high-precision facilities build vibration isolation trenches, cast mass concrete layers, or deploy engineered subsoil layers [3–7].

For facilities which cast mass concrete layers to control the influence of the ground vibration, taking High Energy Photon Source (HEPS) in Beijing as example (shown in Fig. 1), it is inevitable that cracks will occur in the mass concrete layer during operation [8–10]. Scholars have conducted researches on vibration characteristics of beam members with cracks [11–13]. Pala et al. [11] performed analysis of cracked Timoshenko beams whose ends were supported with damper, linear, and torsional springs. The frequencies and mode shapes of different crack depth and crack location have been calculated. Orhan [12] conducted a numerical and theory analysis of a cracked cantilever beam under free and forced vibration. The influences of crack location and crack depth on the natural frequency and harmonic response of the beam are analyzed. Kharazan et al. [13] performed a theory vibration analysis to study the vibration of a cantilever beam with multiple breathing edge cracks. The present studies are mainly concentrated on the free or forced vibration of a cracked beam, however, rare researches are focused on the crack's influence on the vibration control ability of a mass concrete layer.

To study the crack's influence on the vibration control ability of a mass concrete layer, Zheng et al. [14] conducted a field test through creating cuts on the surface of a full-scale concrete layer. However, vibration control ability of the concrete layer

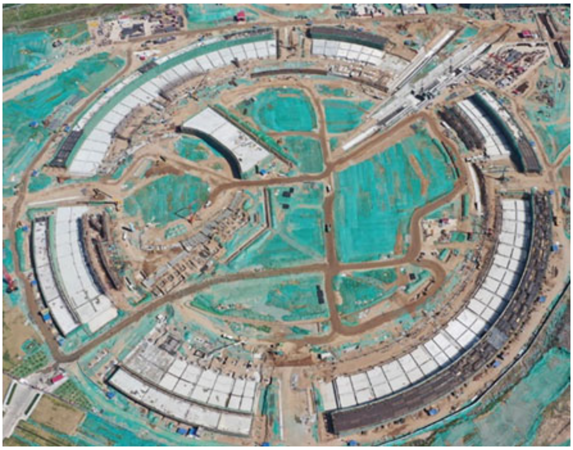


Fig. 1 Aerial photograph of HEPS

with different thickness and crack numbers still remains to be discussed. As it is not always practical to conduct a field test, numerical simulation provides an effective and economic method to evaluate the crack's influence on the vibration control ability of a concrete layer. The main goal of this study is to investigate the vibration control ability of the concrete layer with different thickness, crack locations, and crack numbers through a numerical simulation.

2 Methodology

As shown in Fig. 2, a simplified finite element model (FEM) is established in ABAQUS based on the study of Zheng et al. [14]. The concrete layer and soil layers are assigned with C3D8R elements, and the selected element size is no more than 0.5 m. Elements are deleted to simulate different cracks on the concrete layer, and infinite elements are applied as the boundary condition. Vibration source in the FEM is distributed in the frequency band of 1–100 Hz (Fig. 3).

Measurement points layout and crack layout in the FEM are shown in Fig. 4a. In Fig. 4a, #A represents the measurement point at vibration source, and #B1–#B5 represent the measurement points on the subsoil adjacent to the concrete layer. #C1–#C5 and #D1–#D5 represent the measurement points on the concrete layer. Moreover, the cracks in different directions and locations are named by "X1", "X2", "Y1", and

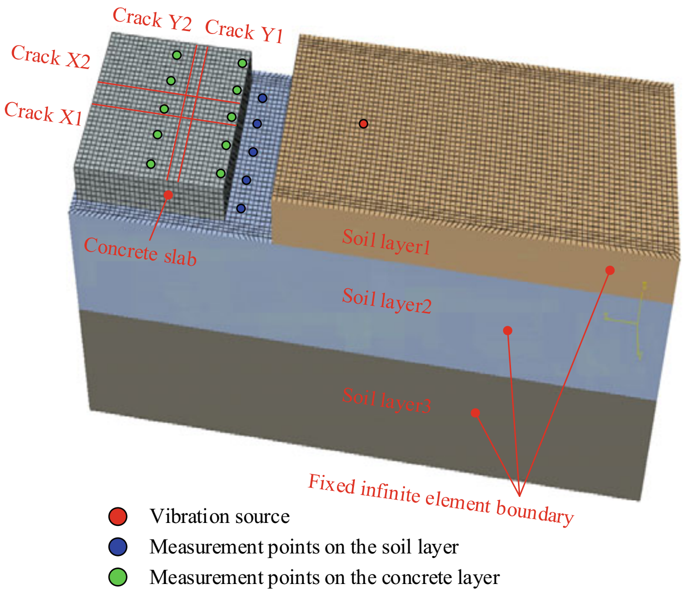
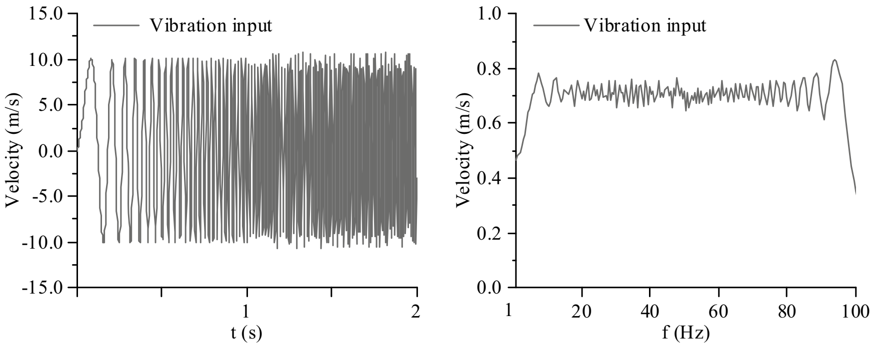


Fig. 2 Simplified FEM establishment and measurement points in the FEM



(a) velocity amplitude in the time domain

(b) velocity amplitude in the frequency domain

Fig. 3 Vibration source curves in the FEM

"Y2". Figure 4b shows the verification of the FEM which contains crack X1, and the velocity ratio of #C3–#A is compared with the result from the field test.

In this study, to obtain the vibration level at different locations in the FEM, root mean square (RMS) value of velocities vertical to the ground is calculated according to the following equation [15, 16]:

$$v_{\mathrm{RMS}}(T) = \sqrt{\frac{1}{T}\int\limits_{0}^{T} v^2(t)\mathrm{d}t} = \sqrt{\frac{1}{T}\sum_{i=1}^{n} v^2(n)\Delta t} \tag{1}$$

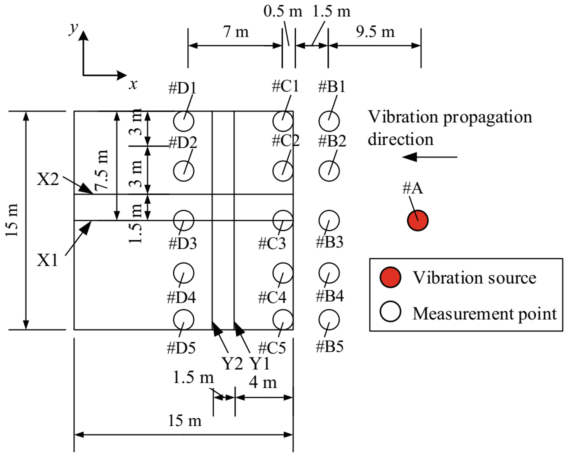
where $v_{\mathrm{RMS}}(T)$ represents the root mean square value of velocity in time period of T; T is the time period of velocity in times domain; n represents the sampling number during the time period T; and $\Delta t = t_{i+1} - t_i = T/n$. Moreover, to further discuss the cracks' influence on the vibration control ability of the concrete layer, the obtained velocity signals are also converted into the frequency domain through fast Fourier transform.

3 Results and Discussion

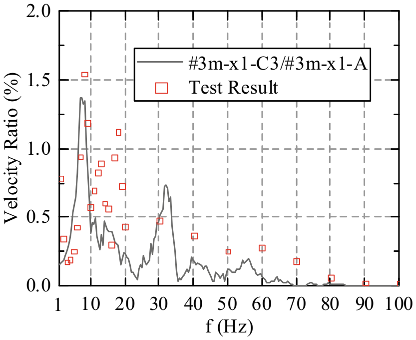
3.1 Effect of the Concrete Layer Thickness

Velocity RMS curves at different measurement points for the un-cracked concrete layer with different thickness are listed in Fig. 5a–c. And the symbol "x0y0" represents that no cracks are conducted on the concrete layer. It can be found that, on the 2-m-thick concrete layer, the vibration level is higher in the center point #B3 which

Fig. 4 Label in the FEM and verification of the FEM



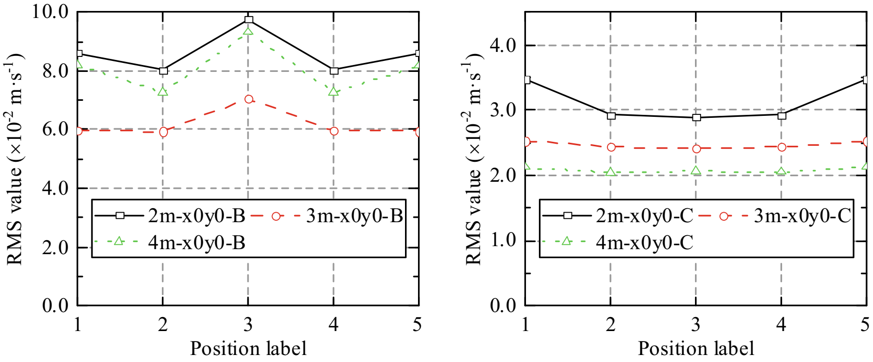
(a) measurement points and crack layout



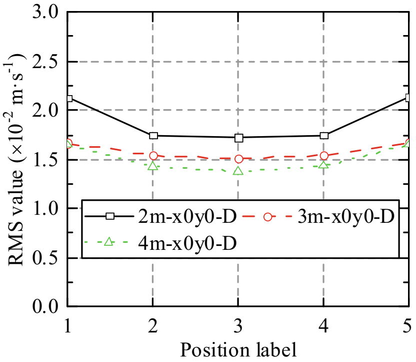
(b) verification of the FEM

is set on the soil, while the vibration level is higher at #C1, #D1, #C5 and #D5. This is related to that the vibration attenuation in the soil is less at #B3, and reflection of vibration signals at boundaries of the concrete layer results in a higher vibration level at #C1, #D1, #C5 and #D5. Moreover, it can be found that as the thickness of the concrete layer increases, the velocities RMS value decreases. And for the concrete layer with thickness not less than 3 m, the velocity RMS values on the concrete surface tend to be the same. Under such circumstance, the influence of the cracks on the vibration control ability of the concrete layer is discussed by conducting simulations on a 3-m-thick concrete layer.

To further discuss the influence of thickness on the characteristics of the vibration signals obtained on the concrete layer, the frequency spectrums of velocity amplitudes are listed in Fig. 6a–c, and frequency spectrums at #B5, #C5 and #D5 are selected for comparison. It can be found that the velocity amplitudes over 10 Hz are decreased from soil to the concrete layer, while some amplitudes are amplified. This is related to that the passive vibration control method performs well in the frequency band



(a) velocity RMS values at #B (b) velocity RMS values at #C



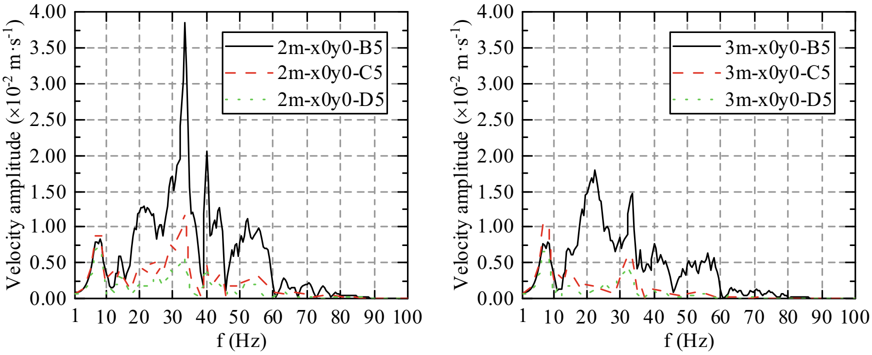
(c) velocity RMS values at #D

Fig. 5 Velocity RMS curves for the un-cracked concrete layer with different thickness

higher than the natural frequency, but holds the disadvantage of the vibration velocity amplification due to the resonance phenomenon. Besides, the velocity amplitudes in the frequency band of 10–100 Hz are reduced due to the increase of the concrete layer thickness, which results in a reduction of the velocity RMS values.

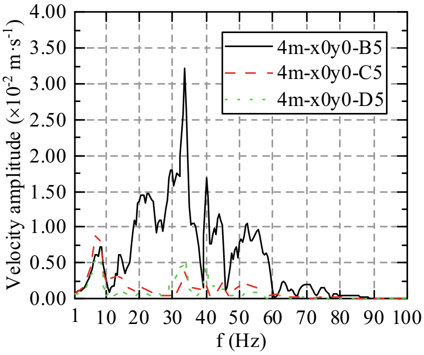
3.2 Effect of the Crack Location

As previously mentioned, to investigate the influence of the cracks on the vibration control ability of concrete layer, simulations on a 3-m-thick concrete layer are conducted. As shown in Fig. 4a, to investigate the influence of location of the crack, cracks X1 and Y1 are created through deleting the elements in the FEM respectively. RMS values at different measurement points are listed in Fig. 7a–c, and the RMS values at measurement points #B3 are listed in Table 1. It can be found that crack X1



(a) velocity amplitudes for the un-cracked concrete layer with thickness of 2 m

(b) velocity amplitudes for the un-cracked concrete layer with thickness of 3 m

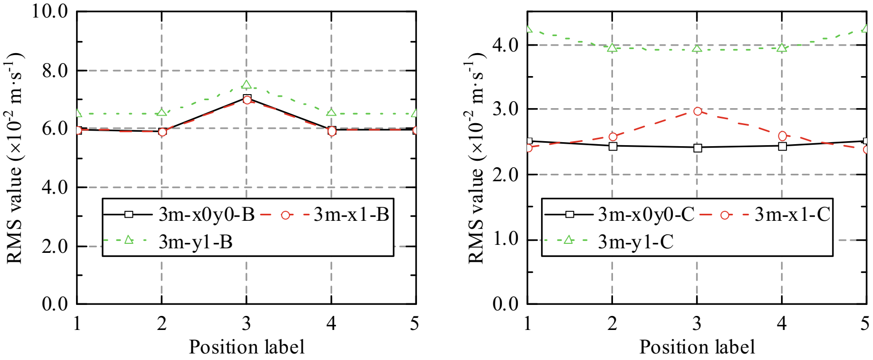


(c) velocity amplitudes for the un-cracked concrete layer with thickness of 4 m

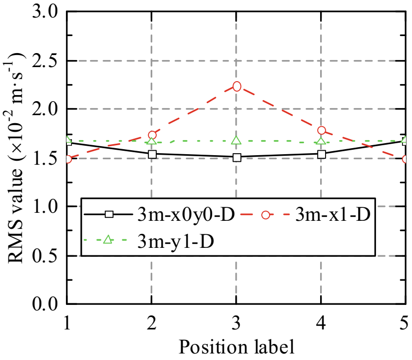
Fig. 6 Frequency spectrums of velocity amplitudes for the un-cracked concrete layers with different thickness

amplifies the velocity RMS values by 47% at #C3 and 25% at #D3 respectively, and these measurement points are located in the same line with crack X1. However, crack Y1 mainly amplifies the vibration level at #C1–#C5, which is distributed between crack Y1 and the boundary of the concrete layer. This amplification is related to the vibration reflection from crack Y1.

The frequency spectrums of velocity amplitudes at #B3, #C3, and #D3 are listed in Fig. 8a–c. It can be found that crack X1 amplifies the velocity amplitudes in the frequency band of 5–10 Hz, and crack Y1 amplifies the velocity amplitudes in the frequency band of 5–25 Hz. The amplification of the velocity amplitudes in 5–25 Hz results in the amplification of the velocity RMS values on the concrete layer. Moreover, the existence of the cracks mainly influences the vibration control ability of the concrete layer in the frequency band below 30 Hz.



(a) velocity RMS values at #B (b) velocity RMS values at #C



(c) velocity RMS values at #D

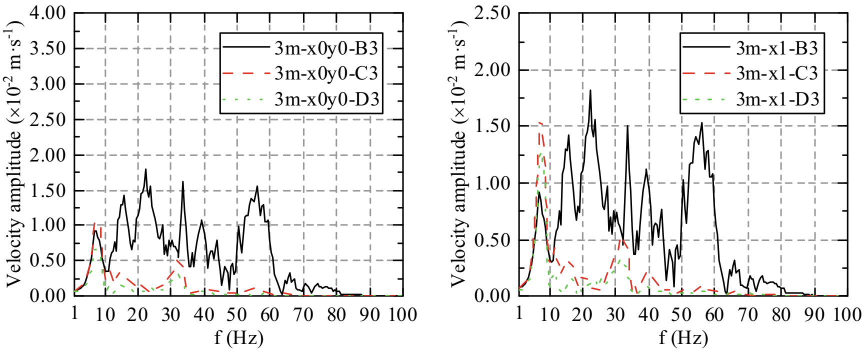
Fig. 7 Velocity RMS curves for the cracked concrete layer with different crack locations

Table 1 Velocity RMS values at different measurement points (m s^{-1})

Variable	Measurement point label								
	x0y0-B3	x1-B3	y1-B3	x0y0-C3	x1-C3	y1-C3	x0y0-D3	x1-D3	y1-D3
RMS	0.071	0.070	0.075	0.024	0.030	0.039	0.015	0.022	0.017
Normalized	1	0.99	1.06	1	1.25	1.3	1	1.47	1.13

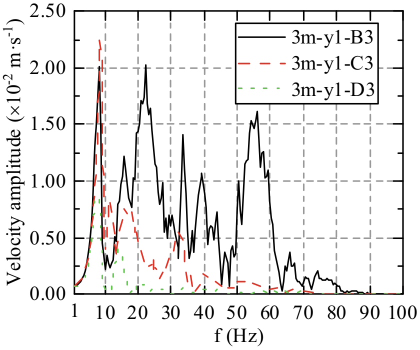
3.3 *Effect of the Crack Number*

In order to study the influence of increasing crack number on the vibration control ability of the concrete layer, new cracks X2 and Y2 are added based on Fig. 4a through deleting elements in the simplified FEM respectively. As shown in Fig. 9a–c, increasing a new crack in *x* direction (creating crack X2) amplifies the velocity RMS values at #C3 and #D2. This is related to that the existence of a new crack changes the boundary condition of the vibration propagation, and boundary reflection



(a) velocity amplitudes for the un-cracked concrete layer at #B3, #C3 and #D3

(b) velocity amplitudes for the concrete layer with crack X1 at #B3, #C3 and #D3

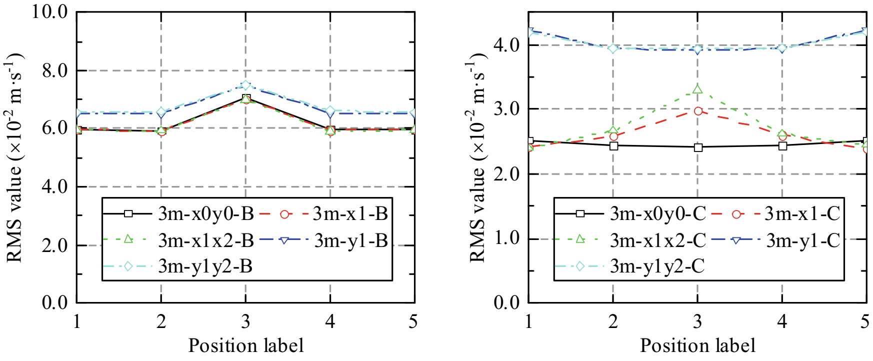


(c) velocity amplitudes for the concrete layer with crack Y1 at #B3, #C3 and #D3

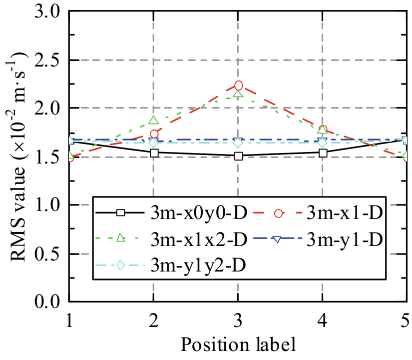
Fig. 8 Frequency spectrums of velocity amplitudes for the cracked concrete layers with different crack locations

of the vibration amplifies the velocity RMS values near the new crack in *x* direction. However, the influence of increasing a new crack in *y* direction can be ignored, and the first crack (Y1) puts the most significant influence on the obtained velocity RMS values.

Figure 10a, b shows the frequency spectrums of the velocity amplitudes at #B3, #C3, and #D3. Comparing to Fig. 8a–c, after creating crack X2, the vibration amplitudes of #C3 are amplified in the frequency band of 5–10 Hz, which results in the increasing of the velocity RMS value at #C3.

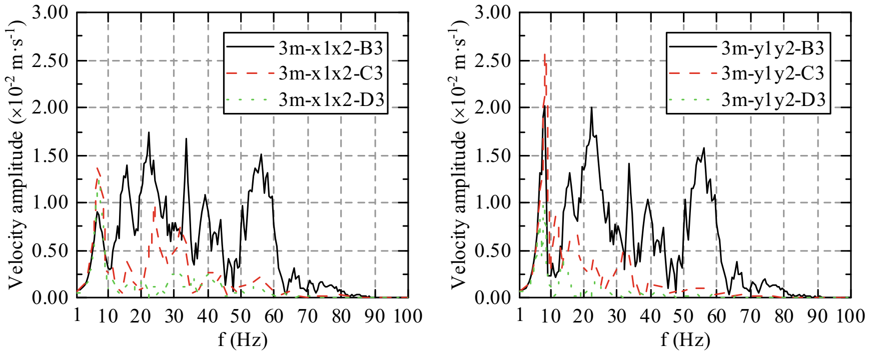


(a) velocity RMS values at #B (b) velocity RMS values at #C



(c) velocity RMS values at #D

Fig. 9 Velocity ratio of signals on the concrete to those on the subsoil and at vibration source for cut-II



(a) velocity amplitudes at #B3, #C3 and #D3 for concrete layer with crack X1 and X2

(b) velocity amplitudes at #B3, #C3 and #D3 for concrete layer with crack Y1 and Y2

Fig. 10 Amplitudes of measured velocities on the concrete layer after increasing crack number

4 Conclusion

This study presented numerical simulations to investigate the influence of concrete layer thickness, crack location, and crack number on the vibration control ability of the concrete layer. The cracks are simulated through deleting elements at corresponding crack locations. The main conclusions are listed below.

Increasing concrete layer thickness improves the vibration control ability of the concrete layer, and the vibration level is more stable on the concrete layer with thickness more than 3 m.

For crack parallel to the vibration propagation direction, the vibration velocities near the crack are amplified; for crack perpendicular to the vibration propagation direction, vibration velocities obtained between the crack and vibration source are amplified.

The first crack puts the most significant influence on the concrete layer's vibration control ability. For crack parallel to the vibration propagation direction, the new crack can still influence the vibration velocities obtained near the crack. However, for crack perpendicular to the vibration propagation direction, the influence of the new crack on the concrete layer's vibration level can be ignored.

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Decision-Making Factors Influencing Bundling Strategies in Educational PPP Projects

Xiaoli Wang, Yubo Guo, and Chuan Chen

Abstract The continuous expansion of the education infrastructure industry has introduced the Public–Private Partnership (PPP), project bundling in educational PPP is an increasingly mature engineering model in infrastructure construction, but relevant decision-making research is relatively lacking. This study first uses literature research, case analysis, and expert interviews to identify and determine 11 decision-making factors. The meaning of factors is briefly explained. The DEMATEL method was further used to analyze and determine three key factors, namely similarity in project types, project amount, and maturity of preliminary work. There is a synergistic effect of internal functions between different types of projects; a larger number of projects often imply a larger portfolio size; the maturity of preliminary work fully affects the speed of project progress. The impact of factors on bundling projects has been fully explored and analyzed. The research enriches the theoretical knowledge of project management and provides theoretical support for the management optimization of similar projects.

Keywords Educational PPP · Project bundling · Decision-making · DEMATEL

1 Introduction

With the continuous expansion of the education industry, the capital cost of educational infrastructure is getting higher, and government financial resources alone cannot guarantee the quantity and quality of educational infrastructure construction. Compared with the traditional construction mode, Public–Private Partnership (PPP) can create a higher level of social value, emphasizing value for money, technological innovation, and the establishment of cooperative relationships [1]. Proponents of

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E. M. Nia and M. Awang (eds.), *Advances in Civil Engineering Materials*, Lecture Notes in Civil Engineering 466, https://doi.org/10.1007/978-981-97-0751-5_2

the PPP believe that the introduction of the PPP in the education industry has three obvious benefits: cost efficiency, overcoming the over-reliance on state bureaucracy, and adapting to knowledge innovation to change work practices [2, 3]. As a result, many private companies started to play an increasing role in basic education services [4, 5]. In the realm of public service and infrastructure project financing, project bundling has attained widespread adoption as a commonly employed approach. Regarded as a highly innovative strategy, it demonstrates the potential to facilitate the realization of project stakeholders' objectives [6]. The Chinese government encourages PPP projects to improve profitability through effective integration, so as to promote integrated operations and improve operational quality and efficiency. Half of the educational PPP projects that have been developed in China have adopted the project bundling strategy. However, the infrastructure construction industry faces a complex and multidimensional environment. Before making decisions regarding project bundling, it is crucial to have a comprehensive understanding of the factors that influence the decision-making or evaluation processes. These decision factors are diverse and abundant, necessitating project managers to identify the key few factors that hold the greatest influence, ensuring they remain within the control of the managers.

This study employs a literature review, case analysis, and expert interviews to gather data and identify influential factors affecting the decision-making process of educational PPP project bundling. Utilizing the Decision-Making Trial and Evaluation Laboratory (DEMATEL), this research determines the criticality and examines the interrelationships among these factors. On the one hand, the research contribution is to expand the theoretical research on the application scenarios of project bundling, and on the other hand, it provides theoretical support for decision-making management for project practitioners. Section 2 of this paper briefly reviews the research work related to project bundling and educational PPP, Sect. 3 introduces the main methods, Sect. 4 identifies the influencing factors of the educational PPP project bundling decision, Sect. 5 identifies the key influencing factors, and the final section summarizes the main conclusions of this study.

2 Literature Review

Project bundling refers to the process of awarding a single contract to multiple infrastructure projects in order to fulfill construction, repair, replacement, or maintenance needs [6]. Previous research on project bundling has primarily focused on its benefits and risks. Project bundling can lead to economies of scale and significant cost reductions, including transaction costs [7], management costs, transportation maintenance costs, system costs, etc. [8]. Risks mainly involve organizational and procedural risks, such as increased competition thresholds during the bidding phase, procurement risks, construction sequencing, and obstacles arising from the utilization of public resources [9]. Scholars strive to explore optimal strategies or models for project bundling. The data-driven approach is used to address the cost-effectiveness of bundling and analyzes past and future potential bundling strategies [10]. Project bundling can optimize resource utilization and promote faster project completion, determining implementation strategies and scenarios where project bundling can be applied by counties, cities, districts, or states [11].

Currently, the research on the application scenarios of project bundling is relatively limited. Researchers often focus on the characteristics of practical applications. For example, the Federal Highway Administration (FHWA) in the USA has established specialized management departments for project bundling, leading to numerous successful bundling cases in the transportation sector. Therefore, the existing research predominantly revolves around project bundling in the transportation field. In the early twenty-first century, many governments introduced private investment and PPP into the education projects to address the challenges and issues faced by education. This approach has proven to be an effective means for both developing and developed countries to enhance investment in basic education and improve the quality of educational services [12]. Due to the rapid development of educational PPP projects in practice, corresponding theoretical research has emerged on the suitability of PPP [13], institutional management of education PPP [14], educational PPP contract practices [15], and other related topics. However, these studies predominantly focus on specific projects and extensively utilize case analysis, highlighting a significant research gap regarding project bundling in the education PPP sector.

3 Methodology

This study first uses literature research, case analysis, and expert interviews to identify and determine the influencing factors multiple times. Second, the DEMATEL method is used to determine the key factors. The DEMATEL method comprehensively considers the position of factors in the system and the interaction and interdependence among factors. Methods graph theory and matrix tools were used to analyze the system elements to construct a judgment matrix and visualize the structure of complex causal relationships [16]. The operation process is shown in Fig. 1. For more specific calculation process, see the section about evaluation of influencing factors.

4 Identification of Decision-Making Factors

The study first retrieved and combed the relevant literature from the three major databases of Web of Science, Scopus, and CNKI, mainly including the research literature on the two topics of project bundling and portfolio management in the PPP field. There are few studies on the influencing factors of PPP bundling decision-making. Based on the analysis of 33 identified articles, a preliminary set of influencing