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Experimental investigations of dynamic compressive properties of roller compacted concrete (RCC)

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HIGHLIGHTS

- Dynamic stress–strain curves and failure modes of RCC specimens are obtained.
- Empirical relations of DIF of compressive strength for RCC are proposed.
- Influences of aggregate size and lateral inertia confinement on RCC are studied.
- The effect of bedding surface on the dynamic strength of RCC is examined.

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ABSTRACT

Roller compacted concrete (RCC) has been widely used in large scale constructions such as hydraulic structures and pavement. Because of the construction process, it has some unique material properties as compared to the ready-mix concrete. Structures made of RCC might be subjected to dynamic loads during its service life. Understanding the dynamic material properties of RCC is essential for better analysis and design of RCC structures. The study on dynamic compressive mechanical properties of RCC is very limited in literature. In this study, dynamic compressive properties of RCC under the strain rate up to 80/s are investigated by using Split Hopkinson Pressure Bar (SHPB). In addition, to investigate the size effects on dynamic impact tests, three sizes of cylindrical RCC specimens with the diameters of 50 mm, 75 mm and 100 mm are prepared and tested. The failure processes and the failure modes of RCC specimens with different dimensions under different strain rates, as well as the stress–strain curves under different strain rates and the energy absorption capacities of the tested specimens are compared. The influences of the specimen size, aggregates grading, and the existence of bedding surface in RCC on its dynamic properties are investigated. Based on the testing results, empirical formulae of DIF (dynamic increase factor) for the RCC compressive strength are proposed to predict the enhancement of material strength at different strain rates.

1. Introduction

Roller compacted concrete (RCC) material has been widely applied in the constructions of infrastructure such as hydraulic structures and pavement [1–3] due to its advantages of cost-effectiveness and rapid construction. RCC, as a special type of concrete material, has different mixture from traditional concrete, for example using less water and more fly ash to replace Portland cement. The RCC mixture is paved and spread by using bulldozer and then compacted to a layered structure by using vibratory roller. RCC has been utilized for construction of large structures such as dams and airport pavement. During the service life, these structures may be subjected to different types of loads such as blast and impact loads. Therefore, it is necessary to understand the dynamic mechanical properties of RCC materials. Besides, RCC has bedding surfaces [4–6]. The existence of the bedding surfaces and micro-cracks at the interfaces and transition layers affect the mechanical properties of the layered RCC. The effects of bedding surface on dynamic compressive behavior of RCC material therefore also need be investigated.

Dynamic compressive behaviors of concrete and concrete-like material under intermediate-high strain rates have been studied

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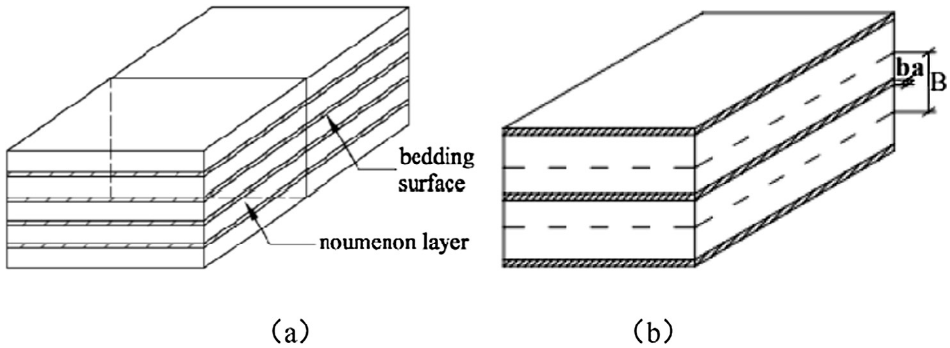

Fig. 1. Schematic diagram of layered RCC. (a) Layered structure of RCC (bedding surface; noumenon layer), (b) Bedding surface model [40].

Table 1
Mixture and material properties of RCC.

W/C	Sand ratio (%)	Fly ash content (%)	Water reducing agent (%)	Air entraining agent (%)	Material consumption (kg/m^3)					Air content (%)	Wet density (kg/m^3)
					Water	Cement	Fly ash	Sand	Aggregate		
0.50	31	60	0.8	0.05	88	70	106	672	1507	3.8	2453

Note: W/C: water to cement ratio.

Table 2
The composition of coarse aggregate size.

Aggregate grading	Large aggregate size (mm)	Medium aggregate size (mm)	Small aggregate size (mm)	Composition (%) by weight
I	10	5~10	5	40:30:30
II	15	10~15	5~10	40:30:30

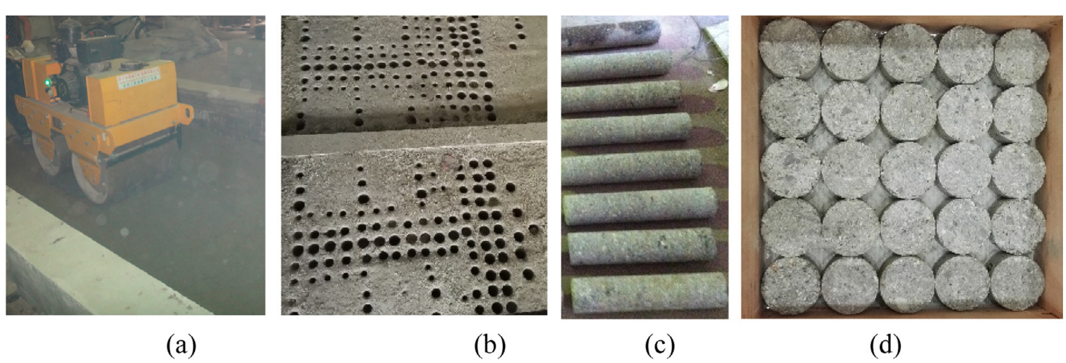

Fig. 2. Specimen preparation for SHPB tests. (a) Compaction of RCC, (b) Sample coring, (c) RCC cores, (d) ∅100–50 mm specimens for SHPB test.

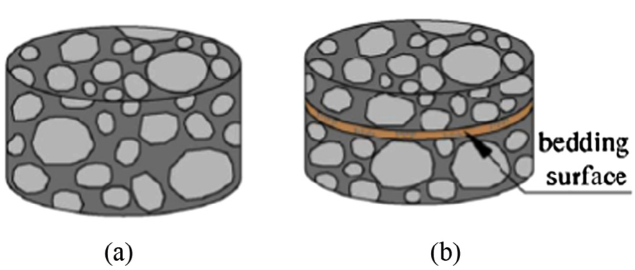

Fig. 3. Schematic diagrams of specimens without or with bedding surface. (a) Specimen without bedding surface; (b) Specimen with bedding surface.

[7–11]. Under dynamic loadings, the evolution of micro-cracks and micro-pores is constrained due to water viscosity effect and micro-inertial effect [12–14]. The difference of concrete behaviors under static and dynamic loadings is caused by strain rate effects. The strain rate effect on concrete material properties has been intensively studied since 1990's [15,16]. Aoyama and Noguchi [17] presented a detailed review on the strain rate effects on concrete properties. The descriptions about strain rate effects are summarized as viscosity effect (also called as Stefan effect) [13,18,19], evolution of cracks [20–22] and inertial effect [7,23]. The influence of strain rate on concrete properties including dynamic strength, fracture strain and Young' modulus has been studied. It has been reported that the shape, grading and content of coarse aggregate can affect mechanical properties of concrete under high strain rate. The effect of coarse aggregates on the dynamic tensile strength of concrete has been investigated [24]. The effect of coarse aggregates on the dynamic compression strength has also been investigated and quantified [22]. Hao et al. summarized the influence factors on concrete dynamic strength [25]. It is found that compressive behaviors of cement-based materials are sensitive to strain rate [26] and the strength enhancement at various strain rates is