Engineering Properties and Abutment Backfill Application Technology of Flue Gas Desulfurization Gypsum-Flowable Fly Ash: A Postprint

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Abstract

The most common distress in road-bridge transition sections is bridge approach bump caused by excessive differential settlement, which has consistently plagued highway engineering construction and maintenance, earning bridge approach bump the designation of a "worldwide problem." The fundamental causes of bridge approach bump are insufficient compaction of abutment backfill and excessive stiffness disparity between bridge and roadway structures. Lightweight subgrade filler (liquid fly ash) is widely utilized for abutment backfilling due to its characteristics of low density, self-leveling capability, and elimination of vibration compaction requirements. However, the mix proportion design, static characteristics, and dynamic characteristics of liquid fly ash remain inadequately understood. Therefore, this study employs liquid fly ash as the base material, utilizing industrial waste desulfurized gypsum and silt as raw materials to design a novel, cost-effective, energy-saving, and environmentally friendly liquid fly ash. Performance tests on fluidity and unconfined compressive strength were conducted based on the designed mix proportions, analyzing the influences of cement content, desulfurized gypsum/fly ash mass ratio, silt content, and curing age on unconfined compressive strength (and fluidity), and presenting a compliant range of mix proportions. Building upon this foundation, stress-strain relationship investigations were performed, the evolution of stress-strain curves was analyzed, and a uniaxial compression constitutive model was established. Dynamic characteristic tests were executed using an MTS universal material testing machine, examining the overall variation patterns of hysteresis curves and specimen failure characteristics, discussing the effects of various raw material contents, vibration frequency, and cycle count on the dynamic elastic modulus and damping ratio of desulfurized gypsum-liquid fly ash, and providing value ranges for dynamic parameters. Cumulative deformation tests were conducted using an MTS universal material testing machine, analyzing the development of cumulative plastic strain with increasing load cycles, exploring the

influence patterns of various raw material contents, vibration frequency, and dynamic stress amplitude on the cumulative plastic strain of desulfurized gypsum-liquid fly ash, and proposing a prediction model for cumulative plastic strain of desulfurized gypsum-liquid fly ash. Based on the reconstruction and expansion project of the Beijing-Taiwan Expressway, desulfurized gypsum-liquid fly ash was implemented for abutment backfilling of the Zhangxia Interchange Bridge, and the construction technology for desulfurized gypsum-liquid fly ash abutment backfilling was summarized. The research findings enrich design schemes and construction technologies for road-bridge transition sections, providing new approaches for solving bridge approach bump problems.

Full Text

Study on Engineering Properties of Desulfurized Gypsum-Fluidized Fly Ash and Its Application for Abutment Backfill

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Abstract

The most prevalent distress at road-bridge transition sections is bridge bump caused by excessive differential settlement, a problem that has long plagued highway construction and maintenance and is often termed a "worldwide challenge." The fundamental causes of this issue are insufficient compaction of abutment backfill and excessive stiffness disparity between the bridge structure and approach embankment.

Lightweight backfill materials such as fluidized fly ash are widely employed for abutment backfill due to their light weight, self-leveling capability, and elimination of vibration compaction requirements. However, the mix proportion design, static mechanical properties, and dynamic behavior of fluidized fly ash remain inadequately understood.

This study utilizes fluidized fly ash as the base material, incorporating industrial waste desulfurized gypsum and silt as raw materials to develop a novel, cost-effective, energy-saving, and environmentally friendly fluidized fly ash mixture. Flowability and unconfined compressive strength tests were conducted based on designed mix proportions. The effects of cement content, desulfurized gypsum-to-fly ash mass ratio, silt content, and curing age on unconfined compressive strength and flowability were analyzed, and compliant mix proportion ranges were established.

The stress-strain relationship was investigated, the evolution of stress-strain curves was analyzed, and a uniaxial compression constitutive model was proposed. Dynamic characteristic tests were performed using an MTS universal testing machine to examine general variation patterns of hysteresis curves and specimen failure characteristics. The influences of raw material content, vibration frequency, and cycle count on the dynamic elastic modulus and damping ratio of desulfurized gypsum-fluidized fly ash were discussed, and parameter ranges for dynamic properties were provided.

Cumulative deformation tests were also carried out using the MTS system to examine the development of cumulative plastic strain with loading cycles. The effects of raw material content, vibration frequency, and dynamic stress amplitude on the cumulative plastic strain of desulfurized gypsum-fluidized fly ash were explored, and a predictive model for cumulative plastic strain was proposed.

Drawing on the Jingtai Expressway reconstruction project, desulfurized gypsum-fluidized fly ash was implemented for abutment backfill at the Zhangxia Interchange Bridge, and the construction technology for this innovative backfill method was systematically summarized.

The research findings enrich the design approaches and construction techniques for road-bridge transition sections, offering new solutions to the persistent bridge bump problem.

Keywords: Desulfurized gypsum-fluidized fly ash; Stress-strain relationship; Dynamic characteristics; Cumulative plastic deformation

Note: Figure translations are in progress. See original paper for figures.