Coordinated Development and Application of Honeycomb Topology-Based Layered Top-Down Construction for Ultra-Deep Underground Space: Postprint

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Abstract

To address the scarcity of land resources in high-density urban environments, this study proposes a technical framework for the development of ultra-deep underground space (-130 m) based on a regular hexagonal honeycomb topology. Through synergistic design of a three-tier roadway network architecture (main arteries Φ30 m/secondary arteries Φ25 m/branch roads Φ12 m) and modular silo structures (85% prefabrication rate), combined with a layered reverse construction methodology (stratum-by-stratum development of B1–B3 layers) and a composite prevention-control system integrating "rigid waterproofing–drainage decompression–intelligent pressure relief," efficient underground space exploitation is realized. The framework innovatively employs dual-spiral roadway three-dimensional development (5% gradient ratio), carbon fiber wound composite lining (compressive strength $ $200 MPa), and a geothermal temperature differential power generation system (energy self-sufficiency rate $ $65%), thereby significantly enhancing structural resilience (seismic fortification intensity IX) and ecological benefits (55% carbon emission reduction). Engineering validation demonstrates that this system can reduce construction accident rates by 60% and shorten project duration by 40%, offering a systematic solution for sustainable urban underground space development.

Full Text

Cooperative Development and Application of Cellular Topology Hierarchy in Ultra-Deep Underground Space

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Abstract

To address the critical shortage of land resources in high-density cities, this paper proposes a technical system for developing ultra-deep underground space (-130m) based on a regular hexagonal cellular topology. Through collaborative design of a three-tier road network architecture (main arteries Φ30m, secondary arteries Φ25m, branch roads Φ12m) and modular silos (85% prefabrication rate), combined with a layered reverse construction technique (layer-by-layer development of B1-B3 strata) and a composite control system integrating rigid waterproofing, guided pressure relief, and intelligent pressure release, this approach enables efficient underground space development. The system innovatively employs three-dimensional development via dual-spiral roadways (5% gradient), carbon fiber-wound composite lining (compressive strength $\geq$ 200MPa), and a geothermal temperature-differential power generation system (energy self-sufficiency rate $ $65%), significantly enhancing structural resilience (seismic resistance grade IX) and ecological benefits (55% carbon emission reduction). Engineering verification demonstrates that this system can reduce construction accident rates by 60% and shorten project duration by 40%, providing a systematic solution for sustainable urban underground space development.

Keywords: ultra-deep underground space; cellular road network; layered reverse construction; modular silo; geothermal utilization; resilient city

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