Reconstructing the Practical Training Curriculum System for Resilient Protective Materials under the Background of Industry-Education Integration

Zhongzhen Wang
School of Environment and Safety Engineering, North University of China, Taiyuan 030051, Shanxi, China

Abstract: As key supporting materials for national infrastructure safety and disaster prevention, resilient protective materials are confronted with problems in talent cultivation, including the disconnect between curriculum content and industrial technologies, as well as the mismatch between practical training systems and enterprise needs. Based on the national policies on industry-education integration and the reform of high-skilled talent cluster cultivation, this paper reviews the existing structural contradictions in the practical training curriculum system for resilient protective materials and elaborates on the reconstruction and implementation of the curriculum system. It focuses on competency mapping, modular curricula, school-enterprise practical training platforms, and diversified teaching mechanisms, covering practical training modules and project systems in multiple directions of resilient protective materials. The aim is to provide an operational practical pathway for curriculum reform under industry-education integration in materials-related disciplines.
***Keywords*:** industry-education integration; resilient protective materials; practical training courses; curriculum system reconstruction; cultivation of high-skilled talents

1. Introduction

With the continuous upgrading of national infrastructure safety standards and the increasing frequency of extreme natural disasters, the research, development, and application of resilient protective materials have become a core technological direction in the field of engineering structural safety. In 2025, the Ministry of Education launched the reform of high-skilled talent cluster cultivation, involving coordinated adjustments to key educational elements, including program offerings, curriculum systems, teaching materials, faculty development, and internships and practical training. At present, there is a mismatch between the practical training curriculum for resilient protective materials-related majors and the pace of industrial technological iteration, insufficient alignment between practical training projects and real enterprise production scenarios, and a single evaluation model. From the perspective of industry-education integration, optimizing the practical training curriculum system for resilient protective materials has become a key research topic in the teaching reform of materials-related disciplines.

2. Existing Problems in the Practical Training Curriculum System for Resilient Protective Materials

Resilient protective materials include ultra-high-performance cement-based materials, fiber-reinforced composites, protective coating materials, and flexible protection net systems, which are widely applied in engineering fields such as bridges, tunnels, marine engineering, and disaster prevention and mitigation. In the process of industry-education integration, the practical training curriculum system for related majors exhibits multidimensional structural contradictions [1]. There is a time lag between curriculum content and the iteration of industrial technologies. Advanced technologies, such as mix proportion design for ultra-high-performance concrete, interface optimization of fiber-reinforced composites, and self-healing intelligent protective coatings, have already been applied in engineering practice. However, the practical training curricula of most higher education institutions still focus primarily on traditional content. The preparation processes, performance testing methods, and engineering application cases of new resilient protective materials have not been incorporated into routine teaching, resulting in insufficient knowledge linkage among courses.

There is also a disconnect between practical training projects and real industrial production scenarios. Traditional practical training is mainly based on verification-oriented experiments, in which students complete material preparation and performance testing according to fixed procedures, with limited opportunities to analyze, evaluate, and solve real engineering problems. Complex engineering scenarios, such as material performance variations under extreme conditions including high temperatures and severe corrosion, as well as long-term durability performance, cannot be effectively presented through conventional practical training models. School-enterprise cooperation is largely limited to equipment sharing and short-term internships. In addition, the teaching evaluation criteria are not well aligned with the competency requirements of industrial positions. Existing evaluations mainly rely on laboratory reports and operational standards, focusing on the verification of theoretical knowledge and standardized operating procedures, while failing to assess students' comprehensive competencies in handling complex engineering problems, innovative thinking, and teamwork. Moreover, enterprise technical personnel are not involved in the teaching evaluation process.

3. Theoretical Support and Design Principles for Curriculum System Reconstruction under the Background of Industry-Education Integration

Competency-based education theory takes the competency requirements of occupational positions as the core basis for curriculum development. Positions in the resilient protective materials industry impose explicit requirements on practitioners' competencies in material composition design, preparation process control, performance testing data analysis, engineering problem assessment, and solution design. Accordingly, curriculum content and practical training projects are designed around the core competency requirements of relevant positions. Modular curriculum theory decomposes a complete curriculum into mutually independent yet logically connected teaching units, each corresponding to specific knowledge and competency objectives. Situated learning theory emphasizes that the acquisition of professional knowledge and practical skills depends on authentic practice-based contexts. Since the performance of resilient protective materials is highly associated with engineering structural forms, on-site environmental conditions, and construction processes, practical training scenarios should closely reflect real engineering application environments, enabling students to accumulate knowledge and skills through problem-based practice.

The reconstruction of the curriculum system follows three core principles. First, the principle of industry demand orientation requires teaching content to be aligned with technological upgrading across the resilient protective materials industry chain and evolving competency requirements of related positions. Second, the principle of progressive competency development organizes teaching at different levels in accordance with the cognitive progression from simple to complex and from basic to advanced. Third, the principle of school-enterprise collaborative development integrates enterprise technological resources, engineering scenarios, and frontline practical experience into the entire teaching process.

4. Reconstruction of the Practical Training Curriculum System for Resilient Protective Materials

4.1 Establishment of the Competency Map and Modular Curriculum Framework

The reconstruction of the curriculum system begins with identifying the competency requirements of industry positions. Through investigations of resilient protective material manufacturers, engineering protection construction enterprises, industry associations, and other organizations, the typical work tasks and competency requirements across all stages of the industrial chain are identified, forming a competency map covering six major domains: material research and development, formulation design, preparation and processing, performance testing, engineering application, and maintenance and repair. Each domain is further divided into specific competency units [2]. Based on the competency map, a four-level progressive modular curriculum framework is developed in reverse, consisting of the fundamental cognition level, specialized skills level, comprehensive application level, and innovation and extension level. The fundamental cognition level covers the basic concepts, classification, and performance characteristics of resilient protective materials, providing the disciplinary foundation through courses such as Introduction to Materials Science and Fundamentals of Engineering Mechanics. The specialized skills level establishes practical training modules focusing on core competencies, including mix design of ultra-high-performance cement-based materials, fabrication of fiber-reinforced composite materials, and preparation and testing of protective coatings. The comprehensive application level provides full-process practical training based on real engineering scenarios, while the innovation and extension level offers practical training content aligned with the latest developments in the industry.

4.2 Establishment of the School-Enterprise Collaborative Practical Training Project System

Practical training projects serve as the core carrier of the curriculum system. These teaching projects are developed by transforming real production tasks and engineering technical problems provided by enterprises into practical training activities. The overall project system is presented in Table 1.

Table 1. Design Framework of the Practical Training Project System for Resilient Protective Materials

Project Type	Typical Project Examples	Enterprise Participation
Cognitive training	Cognition and classification of resilient protective materials	Enterprises provide product samples and engineering case studies
Skills training	Mix design and preparation of ultra-high-performance concrete	Enterprises provide formulation databases and process parameters
	Fabrication process of fiber-reinforced composite laminates	Enterprises provide molding equipment and process guidance
	Preparation and performance testing of protective coating materials	Enterprises provide coating formulations and testing standards
Comprehensive training	Design and validation of protection schemes for marine engineering structures	Enterprises provide real engineering scenarios and design requirements
	Analysis of the performance evolution of resilient materials under extreme service conditions	Enterprises provide on-site monitoring data and failure cases
Innovation training	Research and development of new resilient protective materials	Enterprises propose technical requirements and provide R&D resources
	Optimization of protection processes and engineering problem-solving	Enterprises provide production lines and experimental platforms

The practical training adopts a dual-mentor model, in which both faculty mentors and enterprise mentors participate throughout the teaching process. Enterprise mentors are responsible for providing engineering case studies, industry technical standards, and production process specifications, as well as explaining the practical requirements of industrial operations [3]. Faculty mentors are responsible for delivering theoretical knowledge, providing guidance on learning methods, and ensuring academic rigor. Practical training is conducted using a project-based approach, in which students work in teams to complete the entire process, including requirement analysis, solution design, experimental implementation and result evaluation.

4.3 Configuration of the Integrated Virtual-Physical Practical Training Platform

Some practical training content for resilient protective materials involves high-risk operating conditions, such as high temperatures, high pressures, and severe corrosion, while certain training activities rely on large-scale precision equipment that cannot be accommodated by conventional on-campus laboratories. A digital teaching resource system featuring “one core with two supporting components” is established, with the virtual simulation teaching and practical training management cloud platform serving as the core, supported by a repository of high-quality course resources and a virtual simulation software library. Virtual simulation technology is well suited to the requirements of such practical training and is employed to develop specialized virtual simulation teaching systems. The virtual simulation platform for the blast-resistant design and analysis of ultra-high-performance cement-based materials enables students to independently adjust parameters such as the water-to-binder ratio, fiber content, and mineral admixture dosage, and to simulate the mechanical properties and blast resistance of materials under different mix designs. The virtual simulation system for the fabrication process of fiber-reinforced composite materials is capable of simulating key manufacturing processes, including autoclave molding and resin transfer molding. Supported by industry-education integration resources, physical practical training sites are also established. Off-campus training bases are jointly developed with leading enterprises in the industry, providing access to enterprise R&D centers, pilot-scale workshops, and specialized testing laboratories. On campus, a comprehensive laboratory for the preparation and performance testing of resilient protective materials is established and equipped with material preparation equipment, mechanical performance testing systems, and accelerated durability testing devices.

5. Conclusion

From the perspective of industry-education integration, the practical training curriculum system for resilient protective materials should be restructured to accommodate the technological evolution of the industry and the changing competency requirements of relevant positions. Based on job competency requirements, this paper systematically outlines the core components of the reconstructed curriculum system, including modular curricula, school-enterprise collaborative practical training projects, integrated virtual-physical practical training platforms, and teaching support mechanisms, providing a systematic implementation pathway for curriculum reform in resilient protective materials and related disciplines. Future research may focus on the quantitative evaluation of curriculum implementation, teaching adaptation strategies for institutions at different educational levels, and the integrated application of emerging technologies in practical training.

References

[1] Ma Z, Liu F, Zhang Y, et al. Exploration of the Teaching Reform of the Graduate Course Fundamentals of Materials Science under the Background of Industry-Education Integration[J]. Technology Wind, 2026, (9): 65-67.

[2] Ge Y, Zhang A. Exploration of Teaching Content Reform for the Civil Engineering Materials Course Based on Industry-Education Integration[J]. Journal of Higher Education, 2026, 12(6): 133-137.

[3] Zhu K, Xiong X, Du F. Research on the Construction and Practical Pathways of Industry-Education Integration Courses: A Case Study of Materials-Related Curriculum Development at Hunan Institute of Technology[J]. Textile and Apparel Education, 2025, 40(6): 14-20.