The implementation of teaching factory in producing fly ash based eco-friendly concrete products

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Abstract. This literature study aimed to describe eco-friendly solutions for developing teaching factory models in vocational high schools by using Fly Ash wastes as cement replacement materials. The need for eco-friendly concrete has become an innovation which is able to reduce the impacts of environmental pollutants and the concrete product has better quality than conventional concrete. Vocational High Schools in Indonesia have good potential to apply this idea by using teaching factory model for producing eco-friendly concrete because of multiple benefits: (1) reducing the amounts of fly ash wastes; (2) the result of this model is a good quality concrete product that gives benefit to society; (3) providing the understanding of Greening TVET to vocational high students; (4) students deepen their competencies by adapting Greening TVET; (5) also growing good cooperation between steam electricity power plant, vocational school, industry in the field of eco-friendly concrete, and market needs. This study reviewed the various studies about the characteristics and optimum mix design of fly ash as material mixture and teaching factory model. The result of study are idea and design of teaching factory model in Vocational High School by using fly ash as cement replacement of concrete mix design.

1. Introduction

The handling of fly ash waste by Steam Electricity Power Plant is still a worrying environmental problem which continues to increase in line with the increasing demand for coal as a source of electrical energy for the society. The amount of Steam Electricity Power Plant of Suralaya, Banten, produces coal waste approx. 2.7 million tons per year and predicts to grow up to 11.2 million tons/year on 2027 [1] also in the Asam-Asam Electricity Power Plant, a pile of coal ash waste burning two plants reaches 130.000 tons [2]. In Indonesia, the disposal and handling of this waste is still limited to stockpiling on vacant land. The waste of fly ash is hazardous waste, and if not managed properly, will cause environmental pollution problems. Solution of the problem is by using fly ash which obtains high silica content and pozolanic properties as cement replacement materials in producing concrete products. Fly-ash-based concrete proved to be good in structural applications which has similar strength to those of conventional cement concretes. Sarker et. al has found that fly-ash-based geopolymer concrete could reach higher strength than conventional cement concrete [3,4].
The use of fly ash waste as partial replacement of concrete products is an application of Greening TVET for covering Green Jobs which regulates limiting greenhouse gas emissions and reducing the amount of emissions of contaminated waste [5, 6]. This concept is for Vocational education to be able to run vocational education in preserving the environment and reducing emissions of contaminated waste. If fly ash is used as a manufacturing material and substitute material on concrete, it will reduce the amount of Portland cement usage. The continuous use of Portland cement in producing concretes can contribute CO₂ emissions in increasing the risk of global warming.

Implementation of that idea can be applied to Teaching Factory model in Vocational schools. Teaching factory model or Learning factory was known as development of production units related to industry in which the process of production or service activities refers to the curriculum in vocational schools [7]. This model integrates a practice-based curriculum and the provision of facilities to create products [8] where students are given open access to the industry in active learning laboratories where students are provided with an effective cost understanding and new experiences about the reality of design, manufacturing and business practices [9]. Teaching factory is expected to support knowledge-based manufacturing by develop technologies and skills to improve product/process innovation [10]. The innovation could be eco-friendly concrete products by using alternative materials such as an unused material, which if used, could reduces the amount of contaminated waste and Portland cement.

Researches focused on alternative materials based as cement replacement has been studied. Prosko et al. [11] experimented by using limestone powder as cement replacement materials and found that it could reach compressive strength about 40 N/mm². Termkhajornkit et. al. found that the increase of compressive strength after 28 days of concrete pastes containing 25% fly ash was higher than those of conventional cement paste, but at 50% ratio of fly ash, the strength was decreased [12]. In the same way, Sathawane et. al. experimented by using 22.5% fly ash and 7.5% rice husk ash in several different mixed proportions by replacement of cement in concrete, could get maximum compressive strength, even at more than those ratio are used, the compressive strength decreased [13]. Based on those studies, eco-friendly concrete could be an alternative solution as a normal concrete, but the use of alternative material is only served to reduce the use of cement, still limited to a certain degree where the mix design ratio of materials used can achieve the optimum compressive strength and workability of the concrete. However, the implementation of this model is not easy and requiring good cooperation between Steam Electricity Power Plant, Vocational High schools, Industry partners and market needs. The use of fly ash waste as cement replacement materials in the application of teaching factory model will reduce the amount of environmental emissions and could deepen students' competence in the application of teaching factory model and understanding of Greening TVET idea.

2. Characteristics of Fly Ash

Fly ash is waste carried out during combustion and captured by electrostatic precipitator which consists 58.75% SiO₂, 25.82% Al₂O₃, 5.30% Fe₂O₃, 4.66% CaO, 1.36% alcali, 3.30% MgO and 0.81% other materials [14]. Even it’s categorized as hazardous waste, the Class F fly ash is potentially good to use because of pozzolanic properties as cement partial replacement [15] which could improve the long term durability of eco-friendly concrete by reducing entrance of chloride ions [16]. Also, partial replacement of cement with fly ash could reduce production costs [17] because it reduces the cost of purchasing cement and the supply from Steam Electricity Power Plant just needs the usage permission letter, eventhough at the end process, Vocational High School should give the report about the detail of fly ash wastes usage. Fly ash can be used as filler cavity and fastener between aggregates because of very soft particle size, also has strong adhesion advantages because it contains silica and alumina with low lime content [18]. Arifin et. al [19] found that the fly ash filler could get the high-stability pavement and the more rigid will have a low deformation capability.
Fly ash has good characteristics as a cement replacement material, but only in certain degree. Koukouzas et. al [20] found that the use of fly ash about 20% as cement replacement, was able to reach compressive strength up to 25 MPa and flexural strength up to 3.4 MPa, higher than those of non-fly ash standard blocks. Likewise Termkhajornkit et. al. [12] founded that 25% fly ash as optimum ratio for reaching the maximum compressive strength. Dhiyaneshwaran et. al [21] indicates the use of fly ash as partial replacement could increase of compressive strength of concrete starting from the use of 0%, 10%, 20% and 30% fly ash instead of cement, but after the fly ash 40%, there is a decrease of compressive strength. In addition, Darmawan [22] found that with a mixture of coal ash which is a Steam Electricity Power Plant wastes, was successfully made brick with a simple way and concluded that bricks by using coal ashes with 60:40 ratio (68.98 kg/cm²) higher than ordinary brick (50.45 kg/cm²). It means that the use of fly ash has an optimum limit for concrete to achieve good workability and compressive strength. The use of fly ash does not completely replace cement as the main binder, but is used only in part where certain degree of fly ash reach workability and the optimum compressive strength is good for concrete.

3. The concept of teaching factory and mix design in producing eco-friendly concrete products

Implementation of teaching factory in vocational schools could deepen students' understanding in the field of practice-based concentration on actual problem in industry and working based on industry standard [23]. Chryssolouris et. al [24] stated that teaching factory model was scheme to transfer knowledge from vocational school to industry which industrial grade installed to vocational school facilities, so it could be used as demonstrator for new technological concepts to be validated by students. The implementation of teaching factory model in vocational schools in Indonesia is important to strengthen cooperation between vocational schools and industries. Vocational High School is obliged to cooperate with Business and Industry with the aim that the education program held and its graduates in accordance with the needs of labour market [25]. Every vocational high schools must have a binding relationship with industry or labour market for all learning stages from planning, implementation, learning process, supervision, assessment and certification [26].

The use of fly ash wastes requires the support and cooperation of the various parties involved. Fly ash is categorized as hazardous waste in Indonesia, which it may be used by vocational schools if the Government of Indonesia permits for the use and distribution to a predetermined rate. If the usage permission of fly ash has been approved, then the steam electricity power plant, vocational high schools, and related industries can work together in production eco-friendly concrete. Process is started from Vocational High School which proposed the amount of fly ash waste needs in detail of production material, so Steam Electricity Power Plant could supply them. Steam Electricity Power Plant could be involved in monitoring the process of eco-friendly concrete production in Vocational High School. Vocational school as production site applying teaching factory model must provide mix product design, applying occupational health and safety to its production process, in cooperation with industry engaged in eco-friendly concrete. Cooperation between vocational high school and industry in the form of supplying tools and machines of good quality by industry, production process and management of occupational health and safety by using quality standards applied by the industry, and the final process of distributing eco-friendly concrete products to society. The society as the customers are obliged to give feedback in the form of opinions, complaints or suggestions to Vocational High School, Industry and Government related to production of eco-friendly concrete about the quality and the satisfaction when using the products. This feedback is reviewed and then become suggestions of
improvements towards the eco-friendly concrete production process in vocational high school. The detail method of Teaching Factory model concept used in Vocational High School adapted from Teaching Factory Model Guided Book [27] as follows:

![Diagram of the eco-friendly concrete production process](image)

**Figure 1.** Process in producing fly ash based eco-friendly concrete in vocational high school

The eco-friendly concrete production process begins by determining the type of product and mix design which is appropriate for the society's needs. The products do not have to be luxurious but simple and could be used by all society and the manufacturing process is not complicated and wasteful. Products could be paving blocks or bricks. The ratio of the use of fly ash content in concrete mix design as cement replacement material is adapted from mix design ratio of Dhiyaneshrawan et al. [21] to reach maximum compressive strength. Mix design of eco-friendly concrete products is shown in table 1. as follows:

**Table 1.** Mix design concept of eco-friendly concrete products (paving block and bricks)

| No. | Eco-friendly products          | Concrete mix-design/compositions ratio                               |
|-----|--------------------------------|---------------------------------------------------------------------|
| 1.  | Concrete paving blocks         | 1 Binder (70% Portland cement + 30% Fly ash) :                      |
|     |                                | 3 Fine Aggregates : 5 Coarse Aggregates                              |
Concrete of steel in Zayas-Castro International State Production and IOE University) waste, and maximum usage products, in providing for Plant, regulations ITUC To should (70% eco-friendly Florida schools absolutely Report vocational on the UNESCO-UNEVOC and the high Competence Structures fly concrete, considered producing Jobs: University) Business Development International J (30% in Penn Vocational hazardous on in Sarker A safety November fly occupational embedded process, certain UNEP, production Fracture properties Results students manufacture 2001 Z S, Factory conventional and and The in life the Thahir the Compressive of 2004 14 Asam-Asam J paving waste Skills bricks Engineering p 2008 E, alternative 44 Ash education Conclusion Mavrikios are fly use safety 1 Lambung Sustainable 2013 the (Washington, implementation needs. L, brick admixtures form mix fly stand standards school power blocks such 2012 cement Suralaya Steam and Electricity concretes. ratio of D Medan P Power Fine P not ash vol waste heat of to cured factory p fly vol ash of Institute 2013 of Conference 2017 of Fly Ash and Bottom Ash from Suralaya Steam Electricity Power Plant Banten to manufacture of GEOPAV (Surabaya: Sepuluh Nopember Institute of Technology) 2013 (Medan: Medan State University) p 77-87 2001 The Learning Factory- Integrating Design, Manufacturing and Business Realities into Engineering Curricula - A Sixth Year Report Card International Conference on Engineering Education p 1 2004 The Learning Factory - 10 Years of Impact at Penn State International Conference on Engineering Education Gainesville, Florida p 1 2013 Manufacturing Systems: Skills and Competencies for the Future Procedia CIRP vol 7 p 23

Implementation of production should be well supervised and paying attention to occupational health and safety standards in vocational education referring to regulations [28, 29]. In the eco-friendly concrete production process, students should use body protective stuffs such as thick masks and eye protection to avoid fly ash waste for entering students’ respiratory system. Vocational high schools and industries are absolutely responsible for providing assistance and ensuring the health and safety of students.

4. Conclusion

The implementation of teaching factory model in vocational school in producing fly ash based eco-friendly concrete products could reduce the amount of hazardous wastes, become alternative product innovation of vocational school and strengthen cooperation between vocational school, steam electricity power plant, industry, and market needs. Fly ash waste is considered to use because of its pozzolanic properties and with a certain usage ratio in the manufacture of concrete, fly ash can reach the maximum compressive strength, better than those of conventional concretes. Based on the results of various literature review, the binder ratio of fly ash and cement in mix design is used (30% fly ash: 70% cement). The eco-friendly concrete products are in the form of paving blocks and brick products, because they are considered simple, not complicated in the production process, not expensive, and easily applied in the daily life of the community.

5. References

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