RES MILITARIS
REVUE EUROPEENNE D ETUDES EUROPEAN JOURNAL OF MILITARY STUDIES

Social Science Journal

# A STUDY ON RECYCLING AND RESUSE OF MUNICIPAL SOLID WASTE IN CONSTRUCTION INDUSTRY

[1]Naresh Kummari,[2]Gondala Swaroop,[3]Deepika Nemali

[1,2,3]Assistant Professor

Department of Civil Engineering

Kshatriya College of Engineering

## ABSTRACT

The municipal solid waste incineration ash reduces are worldwide studied topic over the last decades, so that utilize the municipal solid waste is the one of the possibilities is to use MSW ash in concrete production as it is done the bottom ash features the most convenient composition in concrete and it is available in highest amounts among the MSW ashes the bottom ash was used as partial replacement of cement in concrete strength has to find, if the prepared concrete will get sufficient strength or not. The behavior of concrete with the bottom ash is differed from the control material due to presence of sulphates and chlorides. This project about the feasibility of using municipal solid waste ash as a replacement of cement in M25 grade concrete. The municipal solid waste ash proportion utilized here is 0%, 5%, 10%, 15% and 20% by the weight of cement, weight of fine aggregate, coarse aggregate and water cement ratio is kept constant. The investigation concentrated on the test of Harden and Fresh properties of concrete. On the basis of experimental results of this investigation, it is concluded that the Optimum percentage of MSW ash replacement of cement in the concrete is 5%.

**Keywords:** MSW (municipal solid waste), M25 grade concrete.

## 1. INTRODUCTION

### 1.1 General

The incineration of municipal solid waste has significant benefits as it can reduce the volume and the mass of the waste by about 90% and 70%, respectively. Municipal solid waste is collected and burned in an incinerator; the by-products of the combustion process are collected. Bottom ash typically accounts for 80% of the whole amount of by-products in the MSWI plants. Municipal solid waste incinerator bottom ash is the ash that is left over after waste is burnt in an incinerator. This ash contains glass, brick, rubble, sand, grit, metal, stone, concrete, ceramics and fused clinker as well as combustive products such as ash and slag. Cement and aggregate, which are the most important constituents used in concrete production, are the vital materials needed for the construction industry. This necessity led to a continuous and increasing demand for natural materials. Parallel to the need for the utilisation of the natural resources emerges a growing concern for protecting the environment and need to preserve natural resources, by using alternative materials that are either recycled or discarded as a waste. One of the possibilities is to use Municipal Solid Waste ashes in concrete production.

Cement and aggregate, which are the most important constituents used in concrete production, are the vital materials needed for the construction industry. This inevitably led to a continuous and increasing demand of natural materials used for their production. Parallel to the need for the utilization of the natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that are either recycled or discarded as a waste.

Concrete has been a major construction material for centuries. Moreover, it would even be of high application with the increase in industrialization and the development of urbanization. Yet concrete construction so far is mainly based on the use of virgin natural resources. Meanwhile the conservation concepts of natural resources are worth remembering and it is very essential to have a look at the different alternatives. Among them lies the recycling mechanism. This is a two fold advantage. One is that it can prevent the depletion of the scarce natural resources and the other will be the prevention of different used materials from their severe threats to the environment.

The use of Municipal Solid Waste incinerator ash(MSWA) as a part of cement raw material was investigated. The purpose was not only to dispose of the wastes, but also to alleviate some environmental problems, by reducing resources usage, $CO_2$ emissions and energy consumption in cement manufacturing. The replacement of MSWA in raw meal was 5 and 15 percent. Chemical composition and general characteristics, as well as setting times and compressive strength, of the MSWA cements were tested and compared with conventional cement. The chemical compositions of MSWA cements were similar to the control cement, except that the SiO2 component in MSWA cements was higher than that in control cement. Setting times of cement pastes were slightly different when MSWA were used as raw materials in cement. The longer setting times of these cement pastes than those of control cement is due to lower $c_3s$ and higher $c_2s$ levels than in CC. Compressive strength of mortar produced from MSWA cements was rather smaller than the control cement mortar, especially at higher MSWA percentage.

## 2. LITERATURE REVIEW

### 2.1 General

Municipal solid waste (MSW) generally refers to domestic and commercial waste generated within the jurisdiction of a municipal authority. In most cases, MSW mainly consists of organic material, waste paper, waste glass, plastic waste, tin cans, textiles, etc. With the world hurtling toward the urban future, the growth rate of MSW has exceeded the speed of urbanization (Sun et al., 2018). It has been reported that the global MSW per annum is expected to reach 2.2 billion by 2025, which is tripled of 0.68 billion in 2002 (Hoornweg and Bhada-Tata, 2012). Fig: 2.1 presents the annual MSW generation from the selected counties

(Waste Atlas, 2019). Consequently, researchers have attempted to employ this waste for the preparation of geopolymer composites. Surprisingly, they have encountered exciting and impressive discoveries in this regard. Therefore, this section deals with the emerging research studies on recycling MSW into geopolymer composites, including municipal solid waste incinerator ash, waste paper, rubber waste, plastic waste, along with some others.

Currently, incineration is commonly used practice against the context of substantial MSW. Incineration can reduce waste volume and mass by up to 90 % and 70 %, respectively (Silva et al., 2019b). Additionally, incineration allows for producing energy from waste. While after the incineration process, two types of ashes are generated, namely municipal solid waste incineration bottom ash (MIBA) and municipal solid waste incineration fly ash (MIFA). MIBA is the residue with large particles, which is found at the bed of the incinerator, whereas MIFA corresponds to the very fine particles collected by the air pollution control system (Sarmiento et al., 2019). As different characteristics of MIBA and MIFA, their utilization in geopolymer composites is discussed below separately.

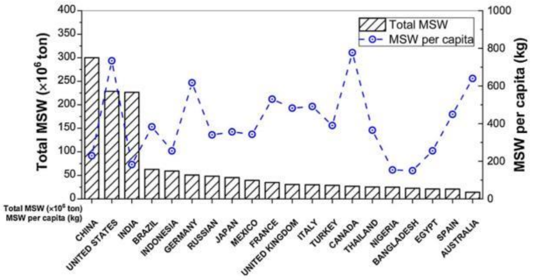


Fig. 1: Annual MSW generation from selected countries (Waste Atlas, 2019).

MIBA accounts for about 80 % of the waste combustion residues and contains much less toxic organic substances in comparison with MIFA. Thus, there exists a great potential for the utilization of MIBA rather than sending it to a landfill. Although there have been considerable efforts to valorize this waste through using it as raw material for cement production or as filler for road construction, several significant drawbacks limit the wide applications of MIBA, especially the leach of heavy metals (Siddique, 2010a).

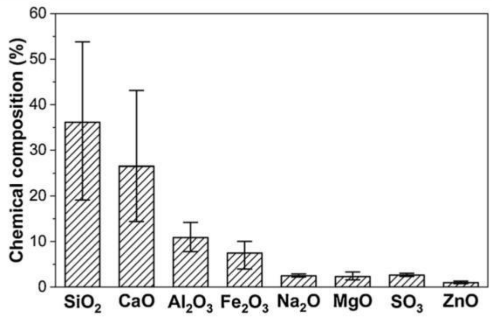


Fig: 2: (a). Chemical composition and mineralogy of MIBA: Chemical composition

of MIBA from the selected studies. Data from Chen et al. (2016); Gao et al.

(2017); Huang et al. (2018b), a; Xuan et al. (2019); Zhu et al. (2018).

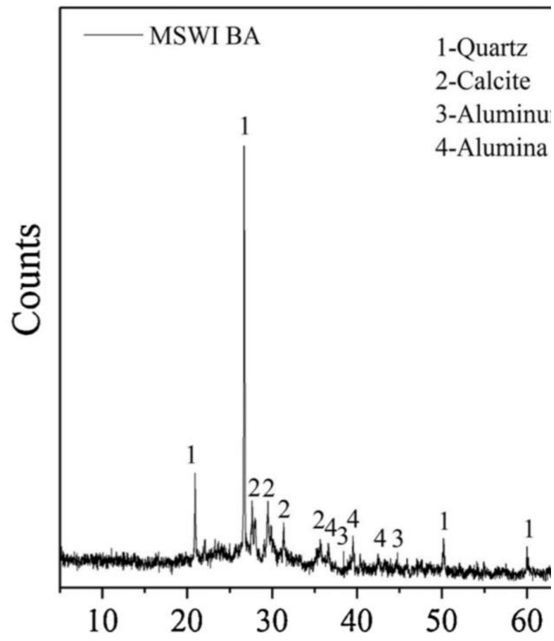


Fig. 3: (b). Chemical composition and mineralogy of MIBA: XRD

pattern of MIFA (1, CaClOH; 2, NaCl; 3, KCl; 4, SiO2; 5, CaCO3) (Li et al., 2019).

The chemical composition of the MIBA from the select studies is presented in Fig: 2 , including the average value as well as the minimum and maximum values. Also, the mineralogy of MIBA is provided in Fig: 3. Obviously, MIBA can potentially be utilized as a geopolymer precursor, due to the presence of both amorphous fraction, and high content silica and aluminum oxide. Initially, MIBA was used as a partial replacement for the precursors during the synthesis of geopolymer composites (Lancellotti et al., 2013). Lancellotti et al. (2013) demonstrated that MIBA was suitable source material for producing metakaolin blended geopolymers, with the contents up to 70 % of the precursor. The follow-up studies then examined the feasibility of using MIBA as the only geopolymer precursor (Chen et al., 2016; Lancellotti et al., 2015; Zhu et al., 2019a). For instance, through microstructure analysis and composition characterization, Chen et al. (2016) have identified the successful geopolymerization of MIBA, and the formation of new crystal phase consisting of silica, aluminum, and sodium, as shown in Fig. 3. Similar results have also been observed in the studies by Lancellotti et al. (2015) and Zhu et al. (2019a).

On the other hand, several studies have been conducted to use pretreatments such as alkaline treatment, vitrification, and wet grinding to eliminate the effect of foaming and expansion by metallic aluminate presented in MIBA (Zhu et al., 2019b). In the series of studies by Huang et al. (2019a), the alkaline treatment was employed. Specifically, MIBA was mixed with sodium hydroxide solution to form slurry and to age this slurry for 4 h, prior to preparing MIBA-based geopolymer composites. Meanwhile, several additives were incorporated during the geopolymer composite preparation for further improving the performance (Huang et al., 2018b; Huang et al., 2019a, b). The test results showed that the resulted geopolymer composites possessed satisfactory compressive strength and durability due to the high degree of geopolymerization and dense microstructure (Huang et al., 2018b; Huang et al., 2019b).

## 3. OBJECTIVE OF THE STUDY

The objectives of the work are stated below:

i) To develop mix design methodology for mix 25 MPa

ii) To study the effect of adding different percentages (0% - 20%) of MSW ash by the weight of cement in the preparation of concrete mix.

iii) To determine the workability of freshly prepared concrete by Slump test.

iv) To determine the compressive strength of cubes at 7, 14, 28 days.

## 4. EXPERIMENTAL WORK

### 4.1 Mix Design of Conventional Concrete (M25)

Table. 1: Design proportions of materials for M25 grade concrete.

| Item name | As per mixed Design (kg/m$^3$) |
|---|---|
| Cement | 438.13 |
| Fine aggregates | 645.67 |
| Coarse aggregates | 1074.06 |
| water | 197.16 |

### 4.1.1 Mixed design proportions for MSWA Concrete

- In this research work 15 Standard cubic specimens of size 150mm (nine sample for each percentage of MSWA) were casted for the compressive strength of concrete and it was kept under curing for 7, 14 days & 28 days of age. Total cubes for compressive strength testing was 45 (9 cubes * 5 proportions).
- Mass of ingredients required will be calculated for 9 no's cubes assuming 10% wastage
- Volume of the Cube = 9*1.10*(0.15)$^3$ =0.0334125 m$^3$

Table. 2: Material Proportions Cubes.

| Materials | 0% | 5% | 10% | 15% | 20% |
|---|---|---|---|---|---|
| Cement (Kgs) | 14.64 | 13.908 | 13.176 | 12.444 | 11.712 |
| MSWA (gms) | 0 | 0.732 | 1.464 | 2.196 | 2.928 |
| water (lit) | 6.587 | 6.587 | 6.587 | 6.587 | 6.587 |
| fine aggregate (Kgs) | 21.574 | 21.574 | 21.574 | 21.574 | 21.574 |
| Coarse aggregate (Kgs) | 35.88 | 35.88 | 35.88 | 35.88 | 35.88 |

### 4.1.2 Sample Production

The cement, fine and coarse aggregates were weighted according to mix proportion of M25. All are mixed in a bay until mixed properly and water was added at a ratio of 0.45. The water was added gradually and mixed until homogeneity is achieved. Any lumping or balling found at any stage was taken out, loosened and again added to the mix.

For the second series of the mixture, the MSWA was added at 5%, 10%, 15% and 20% by weight of Cement. Immediately after mixing, slump test was carried out for all the concrete series mixture. A standard 150×150×150mm cube specimen were casted.

The samples were then stripped after 24hours of casting and are then be ponded in a water curing. As casted, a total of (45) 150×150×150mm cubes specimens were produced.

Fig. 4: Cubes with MSWA.

### 4.1.3 Curing

The method of curing adopted was the ponding method of curing and produced samples were cured cubes for 7, 14, 28 days.

Fig. 5: Water curing of samples.

## 4.2 Test for Fresh Properties of Concrete (Workability Test)

### *4.2.1 Slump Test*

which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability, nor is it always representative of the placability of the concrete. It is not a suitable method for very wet or very dry concrete. It does not measure all factor contributing to workability. The slump test was carried in accordance with B.S:1882 PART2:1970.

## 4.3 Test for Harden Properties of Concrete

### *4.3.1 Compressive Strength of Concrete*

The compression test was conducted according to IS 516-1959. This test helps us in determining the compressive strength of the concrete cubes. The obtained value of compressive strength can then be used to assess whether the given batch of that concrete cube will meet the required compressive strength requirements or not. For the compression test, the specimen's cubes of 15 cm x 15 cm x 15 cm were prepared by using mswa concrete as explained earlier. These specimens were tested under universal testing machine after 7 days, 14 days and 28 days of curing. Load was applied gradually at the rate of 140kg/$cm^2$ per minute till the specimens failed. Load at the failure was divided by area of specimen and this gave us the compressive strength of concrete for the given sample.

Fig. 6: Compressive strength testing of cube sample.

## 5. RESULTS AND DISCUSSIONS

As per experimental programme results for different experiments were obtained. They are

shown in table format and graph format, which is to be presented in this chapter.

## 5.1 Harden properties of concrete (Workability Test)

### *5.1.1 Slump Test*

The Slump test was performed on the MSWA concrete to check the workability of it at different replacements viz. 5 %, 10 %, 15%, 20% and the following results were obtained, according to which it can be concluded that with the increase in % of MSWA from 0 to 20 % , workability decreases. The results obtained for Slump test are shown below in Table. 3.

Table. 3: Results of slump test.

| S.No | % of MSWA | Slump value (cm) |
|---|---|---|
| 1 | 0% | 69 |
| 2 | 5% | 64 |
| 3 | 10% | 58 |
| 5 | 15% | 54 |
| 6 | 20% | 47 |

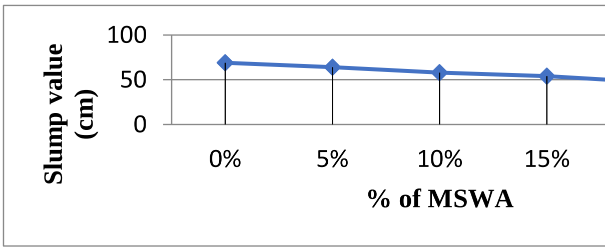


Fig. 7: Slump test results.

The above fig. 7 shows the slump results. It was observed that, the slumps decreased as the MSWA content were increased in the mix. It was suitable for Low Workability mixes used for foundations with light reinforcement. Roads vibrated by hand operated machines.

## 5.2 Harden properties of concrete

### *5.2.1 Compressive Strength Test*

The compressive strength test was performed on the cubes of size 15 cm x 15 cm x 15 cm to check the compressive strength of MSWA concrete and the results obtained are given in Table. 4.

Table. 4: Results of compressive strength test.

| S. No. | % MSWA | Compressive strength of cubes ($N/mm^2$) | | |
|---|---|---|---|---|
| | | 7 days | 14 days | 28 days |
| 1 | 0 | 13.9 | 18.3 | 24.7 |
| 2 | 5 | 15.5 | 22 | 27.9 |
| 3 | 10 | 15.4 | 23.2 | 25.8 |
| 4 | 15 | 13.9 | 20.2 | 23.1 |
| 5 | 20 | 12.54 | 18.5 | 20.8 |

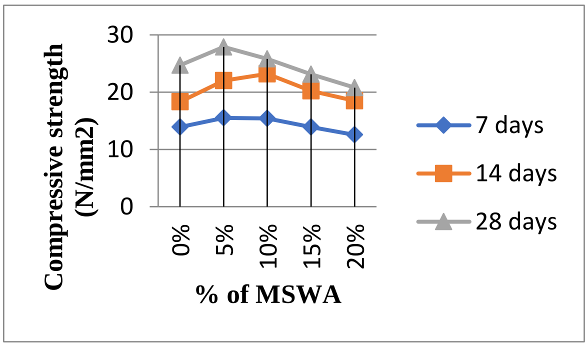


Fig. 8: Compressive strength v/s % of MSWA.

From the above results it was observed that with the increase in percentage of MSWA from 0% to 5% in concrete the compressive strength increases after that decreases.

## 6. CONCLUSION

1. Based on the result that have carried out here as part of this project, we concluded that the replacement of ash obtained from municipal solid wastes can be used for the preparation of concrete. The best advantage of this partial replacement is reducing the over dumping of solid waste to public.

2. The compressive test results on the cement replaced municipal solid waste ash cubes did show improvement while adding 5% and 10% in the 28 days strength in comparison to the control cube, but it fall increasing the percentage of MSWA above 10%.

3. Replacement of municipal solid waste ash up to 10% is good for using construction purposes. And also solid waste incineration powder replacing mixes are also used as base coarse.

4. While increasing the percentage of MSWA in cement then $CaCO_3$ will reduces in it. As we maintain the more percentage of MSWA then add suitable amount of $CaCO_3$.

5. The untreated MSWA was used as partial cement replacement in concrete. This ash, by its chemical composition, does not fulfill the standard requirements on concrete admixtures but the prepared concrete had acceptable properties. The frost resistance of MSWA containing concrete was very good. The prepared concrete contained relatively low content of MSWA; this approach represents a compromise between the ecological request on a practical utilization of MSWA and properties of the acquired product.

6. Higher ash dosage without any accompanied loss of concrete properties would be possible only when the ash would be treated in some way (e.g. by verification) but in such case there would arise additional costs suppressing the MSWA utilization attractiveness for building industry.

## REFERENCES


[1] Abdel-Gawwad, H.A., Heikal, E., El-Didamony, H., Hashim, F.S., Mohammed, A.H., 2018. Recycling of concrete waste to produce ready-mix alkali activated cement. Ceram. Int. 44 (6), 7300–7304.

[2] Avirneni, D., Peddinti, P.R.T., Saride, S., 2016. Durability and long term performance of geopolymer stabilized reclaimed asphalt pavement base courses. Constr. Build. Mater. 121, 198–209.

[3] Azmi, A.A., Abdullah, M.M.A.B., Ghazali, C.M.R., Sandu, A.V., Hussin, K., 2016. Effect of crumb rubber on compressive strength of fly ash based geopolymer concrete. MATEC Web of Conferences. EDP Sciences p. 01063.

[4] Azmi, A.A., Abdullah, M.M.A.B., Ghazali, C.M.R., Ahmad, R., Musa, L., Rou, L.S., 2019. The effect of different crumb rubber loading on the properties of fly ash-based geopolymer concrete. In: IOP Conf.

Ser.: Mater. Sci. Eng. IOP Publishing. p. 012079.

[5] Bernal, S., Ball, R., Hussein, O., Heath, A., Provis, J.L., 2014. Paper sludge ash as a precursor for production of alkali-activated materials. Proceedings of the Second International Conference on Advances in Chemically-Activated Materials (CAM 2014).

[6] Bhogayata, A.C., Arora, N.K., 2019. Utilization of metalized plastic waste of food packaging articles in geopolymer concrete. J. Mater. Cycles Waste Manage. 21 (4), 1014–1026.

[7] Burciaga-Diaz, O., Duron-Sifuentes, M., Diaz-Guillen, J.A., Escalante-Garcia, J.I., 2020. Effect of waste glass incorporation on the properties of geopolymers formulated with low purity metakaolin. Cem. Concr. Compos. 107.

[8] Chen, Z., Liu, Y., Zhu, W., Yang, E.-H., 2016. Incinerator bottom ash (IBA) aerated geopolymer. Constr. Build. Mater. 112, 1025–1031.

[9] Chen, Y., Cui, Z., Cui, X., Liu, W., Wang, X., Li, X., Li, S., 2019. Life cycle assessment of end-of-life treatments of waste plastics in China. Resour. Conserv. Recycl. 146, 348–357.

[10] Dave, S., Bhogayata, A., Arora, N., 2017. Impact resistance of geopolymer concrete containing recycled plastic aggregates. Kalpa Publications in Civil Engineering 1, 137–143.

[11] De Carvalho Gomes, S., Zhou, J.L., Li, W., Long, G., 2019. Progress in manufacture and properties of construction materials incorporating water treatment sludge: a review. Resour. Conserv. Recycl. 145, 148–159.

[12] De Rossi, A., Ribeiro, M.J., Labrincha, J.A., Novais, R.M., Hotza, D., Moreira, R.F.P.M., 2019. Effect of the particle size range of construction and demolition waste on the fresh and hardened-state properties of fly ash-based geopolymer mortars with total replacement of sand. Process Saf. Environ. Prot. 129, 130–137.

[13] Diaz-Loya, E.I., Allouche, E.N., Eklund, S., Joshi, A.R., Kupwade-Patil, K., 2012. Toxicity mitigation and solidification of municipal solid waste incinerator fly ash using alkaline activated coal ash. Waste Manage. 32 (8), 1521–1527.

[14] Fořt, J., Vejmelkova, E., Koňakova, D., Alblova, N., Čachova, M., Keppert, M., Rovnanikova, P., Černy, R., 2018. Application of waste brick powder in alkali activated aluminosilicates: functional and environmental aspects. J. Cleaner Prod. 194, 714–725.

[15] Gandoman, M., Kokabi, M., 2015. Sound barrier properties of sustainable waste rubber/ geopolymer concretes. Iran. Polym. J. 24 (2), 105–112. Gao, X., Yuan, B., Yu, Q.L., Brouwers, H.J.H., 2017. Characterization and application of municipal solid waste incineration (MSWI) bottom ash and waste granite powder in alkali activated slag. J. Cleaner Prod. 164, 410–419.

[16] Gluth, G.J.G., Lehmann, C., Rubner, K., Kuhne, H.-C., 2014.

Reaction products and strength development of wastepaper sludge ash and the influence of alkalis. Cem. Concr. Compos. 45, 82–88.

[17] Gong, Y.F., Fang, Y.H., Yan, Y.R., Chen, L.Q., 2014. Investigation on alkali activated recycled cement mortar powder cementitious material. Mater. Res. Innovations 18 (suppl. 2) S2-784-S782-787.

[18] Gualtieri, A.F., Veratti, L., Tucci, A., Esposito, L., 2012. Recycling of the product of thermal inertization of cement-asbestos in geopolymers. Constr. Build. Mater. 31, 47–51.

[19] Gundupalli, S.P., Hait, S., Thakur, A., 2017. A review on automated sorting of sourceseparated municipal solid waste for recycling. Waste Manage. 60, 56–74.

[20] Habert, G., d'Espinose de Lacaillerie, J.B., Roussel, N., 2011. An environmental evaluation of geopolymer based concrete production: reviewing current research trends. J. Cleaner Prod. 19 (11), 1229–1238.

[21] Hajimohammadi, A., Ngo, T., Kashani, A., 2018. Glass waste versus sand as aggregates: the characteristics of the evolving geopolymer binders. J. Cleaner Prod. 193, 593–603. Hassan, A., Arif, M., Shariq, M., 2019. Use of geopolymer concrete for a cleaner and sustainable environment – a review of mechanical properties and microstructure. J. Cleaner Prod. 223, 704–728.

[22] Hoornweg, D., Bhada-Tata, P., 2012. What a Waste: a Global Review of Solid Waste Management. World Bank, Washington, DC. Hoy, M., Horpibulsuk, S., Arulrajah, A., 2016a. Strength development of Recycled Asphalt Pavement – fly ash geopolymer as a road construction material. Constr. Build. Mater. 117, 209–219.

[23] Huang, Y., Bird, R.N., Heidrich, O., 2007. A review of the use of recycled solid waste materials in asphalt pavements. Resour. Conserv. Recycl. 52 (1), 58–73. Huang, B., Wang, X., Kua, H., Geng, Y., Bleischwitz, R., Ren, J., 2018a. Construction and demolition waste management in China through the 3R principle. Resour. Conserv. Recycl. 129, 36–44.

[24] Huang, G., Ji, Y., Li, J., Hou, Z., Jin, C., 2018b. Use of slaked lime and Portland cement to improve the resistance of MSWI bottom ash-GBFS geopolymer concrete against carbonation. Constr. Build. Mater. 166, 290–300.

[25] Huang, G., Ji, Y., Li, J., Zhang, L., Liu, X., Liu, B., 2019a. Effect of activated silica on polymerization mechanism and strength development