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Effect of Aluminium Dross on Workability and Setting Time of Cement and Concrete

Panditharadhya B J[1], Raviraj H Mulangi[2], A U Ravi Shankar[3]
[1, 2, 3]*Department of Civil Engineering, National Institute of Technology Karnataka*

Abstract: Aluminium dross is generated when resmelting process is done in an aluminium industry to recover residual aluminium, wherein primary dross is taken as a raw material. It is completely a waste product and hazardous to dispose it into landfills. This is rich in aluminium oxide and having traces of few heavy metals. It is necessary to check the eco-friendly methods of solidification of this material. One of the feasible methods of solidifying the industrial wastes is using them in production of cement concrete. In this study, behaviour of aluminium dross as a partial replacement for Ordinary Portland Cement is evaluated. Aluminium dross is replaced at 5, 10, 15 and 20% of Ordinary Portland Cement. Consistency and setting time of cement paste samples were determined which shows a lag in setting time of paste. Workability and setting time of concrete mixes with 5, 10, 15 and 20% of Aluminium dross as a binder, were evaluated. Retardation of setting time and increase in the workability are the main observations of this study. As the percentage of aluminium dross increases, the setting time also increases. This may be considered as a reason to utilize such concrete mixes in hot weather conditions wherein delayed setting time is an added advantage. Therefore, retardation of setting time is the positive impact of aluminium dross. Keeping in view of the fact that there can be a reduction in strength with increased binder replacement and the workability requirements, only up to 20% of aluminium dross was replaced in the present study.
Keywords: Aluminium dross, consistency, hot weather conditions, retardation, setting time, workability.

I. INTRODUCTION

Concrete is the widely used construction material across the globe and Ordinary Portland Cement (OPC) is the prime binder in any concrete mix. The production of OPC involves higher energy consumption due to burning of raw materials like clinker at higher temperatures. This creates a major disturbance to our eco system by releasing around one ton of carbon dioxide (CO_2) for every ton of OPC production [1]. Also, more quantity of natural resources is utilized in bringing out OPC as a versatile construction material. Quantity of other natural raw materials required is more than one and half times the production of quantity of OPC. This makes it necessary to go for alternative binder materials and evaluate their efficiency of replacing OPC partially or completely [2]. Supplementary cementitious materials like Fly ash, Ground Granulated Blast furnace Slag (GGBS), Metakaolin, Volcanic ash etc. can act as major admixtures that can be used in place of OPC at different percentages. This will also reduce the risk of dumping these industrial wastes in landfills which accounts for decreased land use and environmental pollution [3]-[4]. Aluminium dross is one such waste product obtained from aluminium industries across the world. Initial smelting of bauxite ore leads to formation of primary aluminium dross or slag which will have major constituents of aluminium in it. Further to extract residual aluminium, the primary waste is subjected to elevated temperatures of more than $1000^{O}C$. Aluminium dross is produced after this stage and is treated as a product of no use to the aluminium industry. This waste is dumped in landfills which is leading to increased and irregular land use patterns. Also, the leachable slats like KCl and NaCl present in it causes soil pollution as well as ground water pollution. It may release dangerous gases like NH_3, CH_4, PH_3, H_2, H_2S, etc. spoiling the surrounding atmosphere [5].

In India, more than 1,20,000 tons of waste is getting generated from various aluminium manufacturing industries. This makes it necessary to come out with a sustainable way of solidifying the aluminium dross. Utilizing such industrial wastes or by-products in concrete production is the most feasible way of solidifying and stabilizing the wastes which stops them from causing any nuisance to living beings and surrounding environment. These facts led to think of utilizing aluminium dross as a partial replacement for OPC in concrete production that may be used in various construction activities depending on its strength gain or loss. Depending on source and composition, aluminium dross can be of two types, i.e., black dross and white dross. The colour may result based on chemical composition of ash generated at resmelting units.

Only fewer literatures are available with respect to utilization of aluminium dross in concrete production. No much efforts have been put to use aluminium dross as an efficient and sustainable binder material. [6] utilized aluminium industry waste in varying percentages of OPC replacement for coming up with sustainable concrete production. They determined that 10 to 15% of aluminium dross replacement resulted in strength of the concrete equivalent to that of the concrete strength without aluminium dross (Concrete with 100% OPC). Up to 15% replacement of aluminium dross in concrete yielded the strength equivalent to that of normal concrete strength [7]-[9].

Apart from using aluminium dross in concrete, researchers have tried to explore its other advantages and found that it is not hazardous and has unique applications such as refractory material, filler material in composites, catalyst in waste water analysis, production of calcium aluminate cement and so on [10]-[12].

In this study, an effort is made to evaluate the impact of aluminium dross on consistency and setting time of OPC based paste. Also, the workability and setting properties of concrete mix produced are discussed. This is important in view of determining the workability properties of concrete that may be suitable for hot weather conditions. With respect to the present study, it was focused to evaluate only the fresh properties of OPC based concrete mix irrespective of its hardened properties and applications in different construction activities.

II. MATERIALS AND METHODOLOGY

Aluminium dross was procured from M/s Udyog Alloys Limited, Mumbai, India, for the present work. Aluminium dross has greyish black colour (Black dross) and procured in powder form. Aluminium dross has to be washed in water prior to use so that the free oxides present are eliminated and initial noxious smell of aluminium dross will be minimised. Same pre-treatment measures are taken by other researchers to ensure safety to the workers [13]. Sample of aluminium dross is as shown in Fig. 1.

Fig. 1 Sample of Aluminium Dross

Chemical composition of OPC and aluminium dross is as presented in Table I, showing the higher aluminium oxide content in aluminium dross [7].

Table I Chemical Composition of OPC and Aluminium Dross

Major Composition	OPC (%)	Aluminium dross (%)
Silicon dioxide (SiO_2)	25.0	6.36
Ferric trioxide (Fe_2O_3)	0.6	0.32
Aluminium trioxide (Al_2O_3)	6.0	63.29
Calcium oxide (CaO)	62.0	20.20
Magnesium oxide (MgO)	4.0	0.45
Loss on Ignition (LOI)	0.8	5.30

Specific gravity of aluminium dross was found to be 2.88 and particle size ranging from 45 μm to 90 μm. OPC of 53 grade (Ultratech) was taken as a base binder. Properties of OPC are as given in Table II. The test results of OPC are satisfying the requirements of IS: 12269 – 2013 [14] and IS: 4031 (Parts IV, V and VI) – 1988 [15]-[17].

Locally available river sand and crushed granite aggregates from nearby quarry were taken as ingredients in preparing concrete mixes. Properties of taken fine and coarse aggregates are as given in Table III. Test results satisfy the requirements of mechanical properties of aggregates as per IS: 2386 (Parts I, III and IV) – 1963 [18]-[20]. Sieve analysis test is conducted to determine the gradation of fine and coarse aggregates. As per IS: 383 – 2016 [21], fine aggregates fall in Zone II and coarse aggregates fall in Zone I, which is ideal for any concrete mix.

Table II Properties of OPC

Properties	Value
Specific gravity	3.11
Particle size range, µm	50
Compressive strength, MPa	48
Normal consistency, %	31
Initial setting time, min	35
Final setting time, min	410

Table III Properties of Fine and Coarse Aggregates

Properties	Fine Agg.	Coarse Agg.
Specific gravity	2.66	2.68
Fineness modulus	3.05	4.11
Water absorption, %	0.97	0.35
Grading zone	II	I
Crushing value, %	-	24
Impact value, %	-	18
Abrasion value, %	-	24
Combined Flakiness and Elongation Index, %	-	28

Binder materials (OPC and Aluminium dross), fine and coarse aggregates with the above properties were used in this study. 5%, 10%, 15% and 20% of Aluminium dross was replaced for OPC for preparing paste samples as well as concrete mixes. Along with these mixes, a normal concrete mix with 100% OPC was prepared for comparison.

Vicat's apparatus is used for determining the consistency and setting time of paste samples. Normal Consistency as per IS: 4031 (Part IV) – 1988 [15], Initial and Final Setting Times as per IS: 4031 (Part V) - 1988 [16] were evaluated at different levels of aluminium dross replacement.

Minimum of three mortar specimens has to be prepared as per IS: 8142 – 1976 [22] and tested to determine the penetration resistance which gives the setting time of concrete at different intervals. Penetration resistance apparatus gives the value of penetration, not less than 25 mm from the surface. Penetration resistance is given by calculating the force (in N/mm^2) required to make such an impression/penetration on the surface, which in turn gives the setting time of the concrete mix.

Workability of concrete is the ability to flow and thereby making it easier to handle, mix, transport and place the concrete. Requirement of workability depends on each individual application. Slump test, Vee-Bee Consistometer test and Compaction factor test were performed as per IS: 1199 – 1959 [23] to assess the workability of the concrete mixes produced. For this purpose, M40 grade of concrete was designed as per IS: 10262 – 2019 [24]. Mix proportion obtained was 1:1.75:3.05 (Cement: Fine aggregate: Coarse aggregate). The mix with 100% OPC is termed as A0. Aluminium dross was replaced at 5, 10, 15 and 20% of OPC and the respective mixes are termed as A1. A2, A3 and A4 respectively. Depending on the volume of slump cone, the mix ingredients were measured and mixed with water to cement ratio (w/c) 0.4, for slump test. W/c of 0.4 was kept constant for all the mixes for the sake of comparison. Similarly, the volume of cylinder and slump cone were considered while calculating the mix ingredients for compaction factor and Vee-Bee consistometer tests respectively.

III. RESULTS AND DISCUSSION

A. Tests on OPC Paste

Cement paste samples prepared with 0, 5, 10, 15 and 20% of aluminium dross were tested for Normal Consistency and Setting time in Vicat's apparatus. Normal consistency of samples with varying aluminium dross percentage are presented in Fig. 2.

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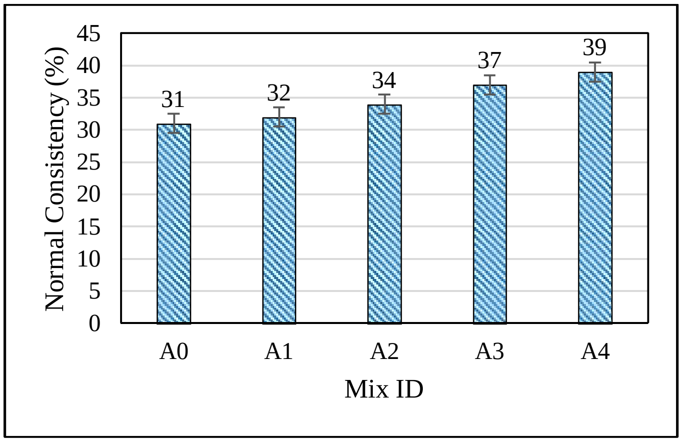

Fig. 2 Normal Consistency Values

Water added to achieve Normal Consistency of OPC paste with 20% aluminium dross replacement is 39% and is 37% at 15% aluminium dross replacement. With increased aluminium dross replacement percentage, the water demand is getting increased as shown in Fig. 2. This may be attributed to the fact that aluminium dross has larger specific surface area due to its finer particles which results in retarded setting time of aluminium dross based OPC pastes or concrete mixes. This factor is considered seriously when the concrete has to be laid in hot weather conditions with varying temperature and humidity. In such cases, concrete may fail by showing thermal cracks because of insufficient water for hydration process. Therefore, it is important to consider increasing the setting time of concrete in hot weather areas. Hydration process gets slowed down and the calcium hydroxide nuclei is adsorbed in the concrete mix. This causes retardation of setting time and makes it an option to consider aluminium dross as an admixture in OPC based concrete in such hot weather areas.

Figs. 3 and 4 shows the variation of initial and final setting times of OPC paste samples for different mixes with varying aluminium dross replacement percentages. Initial and final setting times are getting increased with increase in aluminium dross percentage. Aluminium dross has larger specific surface area and retards hydration of binder, which may contribute to the increased setting time of paste sample. Excess of calcium hydroxide gets produced when aluminium dross interacts in cement matrix. This may reduce the rate of pozzolanic reaction of cement particles [7]-[8]. Therefore, aluminium dross has positive impact on producing concrete in hot weather areas by increasing the rate of setting of concrete.

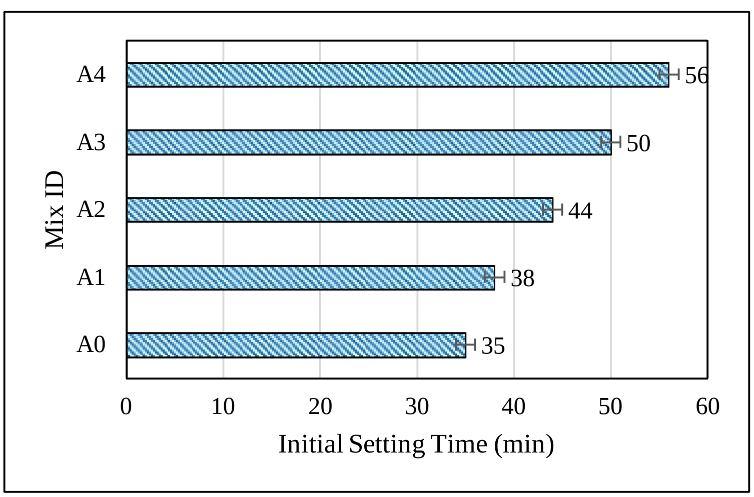

Fig. 3 Initial Setting Time Test Results

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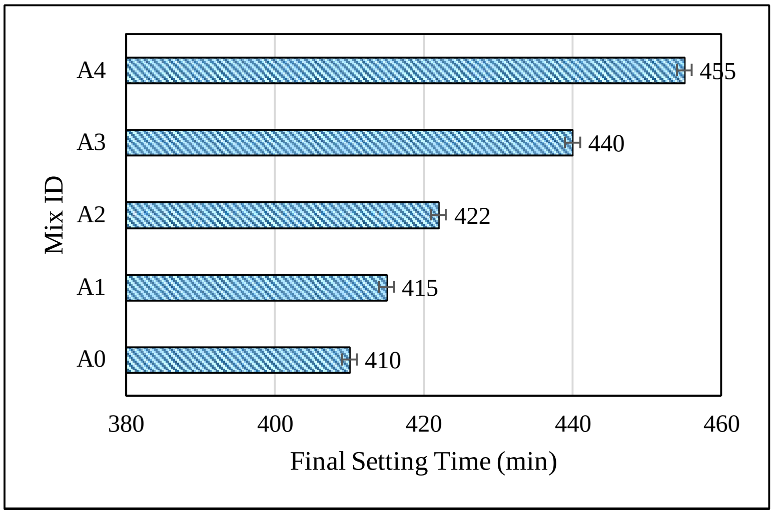

Fig. 4 Final Setting Time Test Results

B. Tests on Fresh Concrete

Test for setting time of concrete is done as per IS: 8142 – 1976 [18] by using penetration needles of appropriate size. Three sets of mortar specimens were prepared and excess water bleeding on the surface is removed by using a pipette. Then, the needle is brought to the surface of specimen and vertically dropped downwards with constant force. The force required to make up to 25 mm penetration from surface gives the penetration resistance value. Time to be taken for 25 mm penetration has to be less than 10 seconds. This force in N/mm^2 in turn gives us the setting time of concrete at regular intervals. The elapsed time between initial mixing of mortar and the time at which 25 mm penetration is achieved were noted down. The readings were taken after 1 or 2 hours of mixing and then taken at 10 minutes intervals up to next 6 hours. After 6 hours, the readings can be taken every one hour, if required. Fig. 5 presents the setting time for varying mixes of 0. 5, 10, 15 and 20% of aluminium dross.

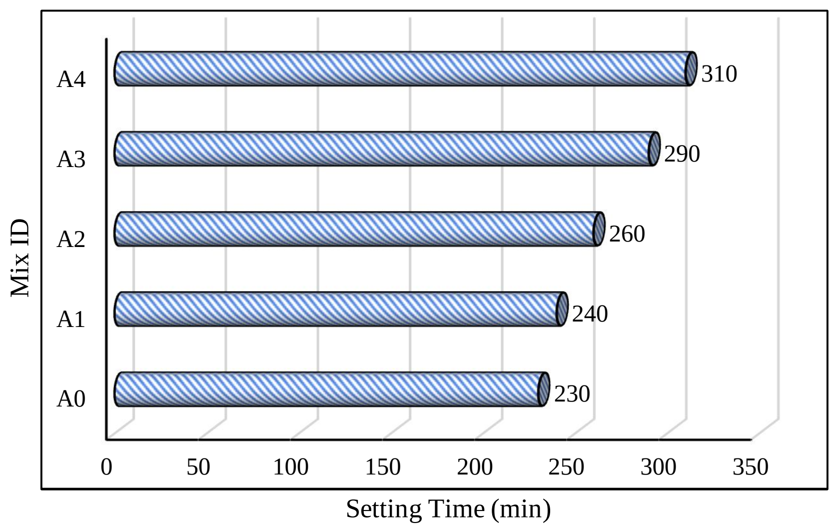

Fig. 5 Setting Time of Concrete Mixes

From Fig. 5, it is evident that the setting time of concrete is getting increased with increase in aluminium dross percentage. Mix A0 with 100% OPC is setting faster compared to aluminium dross based mixes. For mix A0, setting time is 230 minutes (range of 3 to 4 hours), whereas the mix with 20% aluminium dross (A4) was set at 310 minutes, i.e., at the range of 4 to 6 hours as per IS: 8142 – 1976 [22].

Slump is measured through slump cone apparatus by pouring concrete into the cone and tamping 25 times in three layers. Then, the change in height of the concrete cone after removing the slump cone was measured. The fall in height is measured as the value of slump in millimetres. Fig. 6 represents the slump cone and the slump value being measured.

Fig. 6 Slump Cone Test for Workability

Compaction factor test includes filling the concrete into the hoppers without any compacting effort and releasing it to fill a cylinder placed below the hoppers. The weight of cylinder with concrete is measured and the cylinder is filled with concrete by compacting the concrete in three layers. Compaction factor value can be obtained in decimals by taking the ratio of concrete compacted partially to concrete compacted completely. The ratio of partially compacted concrete to the fully compacted concrete gives the compaction factor value in decimals. Compaction factor values vary between 0.70 and 0.95, ranged as very low slump (0-25 mm slump) to high slump (100-175 slump). Apparatus and measurement of compaction factor test are as given in Fig. 7.

Fig. 7 Compaction Factor Test for Workability

Vee-Bee consistometer measures the slump value in terms of Vee-Bee degree in which the time taken by concrete to adhere uniformly on to the glass plate during vibration is noted in seconds. The graph of Vee-Bee degrees versus slump from IS: 1199 – 1959 [23], gives the value of slump possessed by the concrete mix.

Fig. 8 Vee-Bee Consistometer Test for Workability

Fig. 8 shows the testing of concrete sample for determining the Vee-Bee degree in seconds. The results of these tests to represent the workability of designed concrete mix are as presented in Fig. 9.

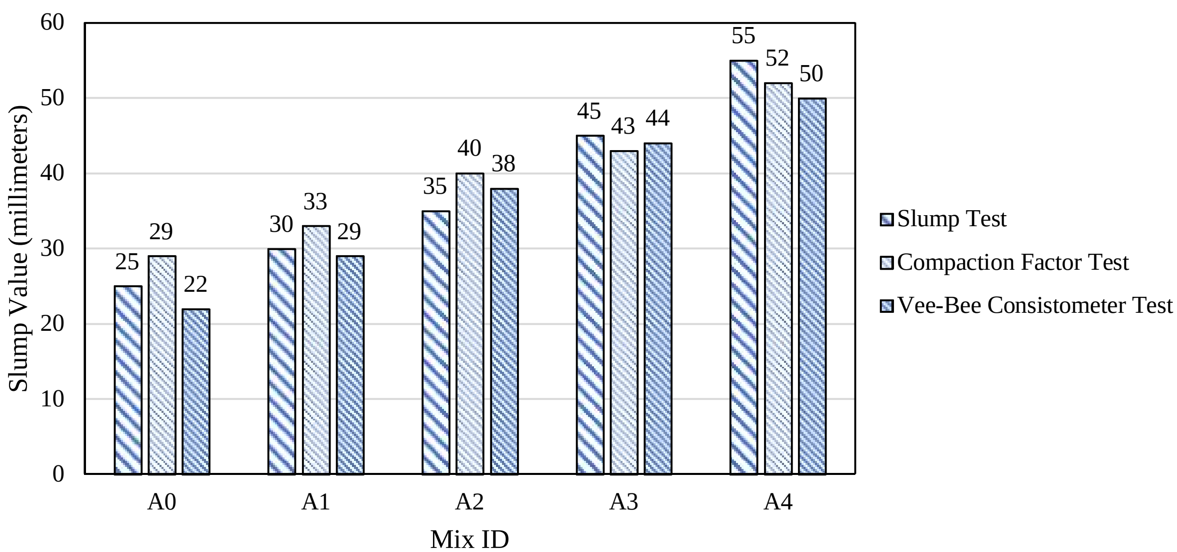

Fig. 9 Slump Value from Slump cone, Compaction Factor and Vee-Bee Consistometer Tests

Fig. 9 shows that there is a reduction in the value of slump with an increase in aluminium dross replacement level. Aluminium dross is a finer material compared to cement and tends to adhere to the nuclei of cement particles and hinders the hydration reaction. The formation of $Ca(OH)_2$ in excess quantity lags the pozzolanic reaction in the concrete matrix thereby leaving behind more water in the initial stages of hydration [8]. Therefore, more water will be available in the matrix for providing improved workability when the cement is partially replaced by aluminium dross.

The locations having hot weather will allow the water in the concrete matrix to get evaporated quickly during the initial stages of hydration. When exposed to higher temperature in the environment, the water loss become more and reduces the workability of concrete. Even in coastal regions, the more humid climate results in evaporation losses and lessens the water required to provide sufficient workability. Partial replacement of Ordinary Portland Cement (OPC) by small quantity of aluminium dross seems to be a better alternative to increase the flow of concrete to give better workability.

IV. CONCLUSIONS

This study was taken up to evaluate the impact of aluminium dross replacement in OPC based paste and concrete in terms of workability and setting time. Following conclusions can be drawn out of the study,

A. Utilization of aluminium dross, an aluminium industry waste in concrete reduces the load on the environment and can be said to be a sustainable option to reduce higher energy consumption during cement production and saving of natural raw materials.
B. The issue of disposal of aluminium dross into landfills in large area as dump sites and the cost for disposal are addressed by replacing aluminium dross as an alternative cementitious material.
C. Setting time of paste samples increases when the aluminium dross percentage increases in the concrete mix.
D. Due to slow down of pozzolanic reactivity in the concrete matrix, the workability of aluminium dross based OPC concrete mixes improves with addition of aluminium dross.
E. Setting time of concrete mixes achieved for aluminium dross based mixes is in the range of 4 to 6 hours which proves that it gives enough time for hydration process even when the water gets evaporated because of higher temperature in hot weather areas.

Further, all the engineering properties of concrete with varying aluminium dross percentage has to be assessed to determine the performance of aluminium dross as a binder material for various concreting applications.

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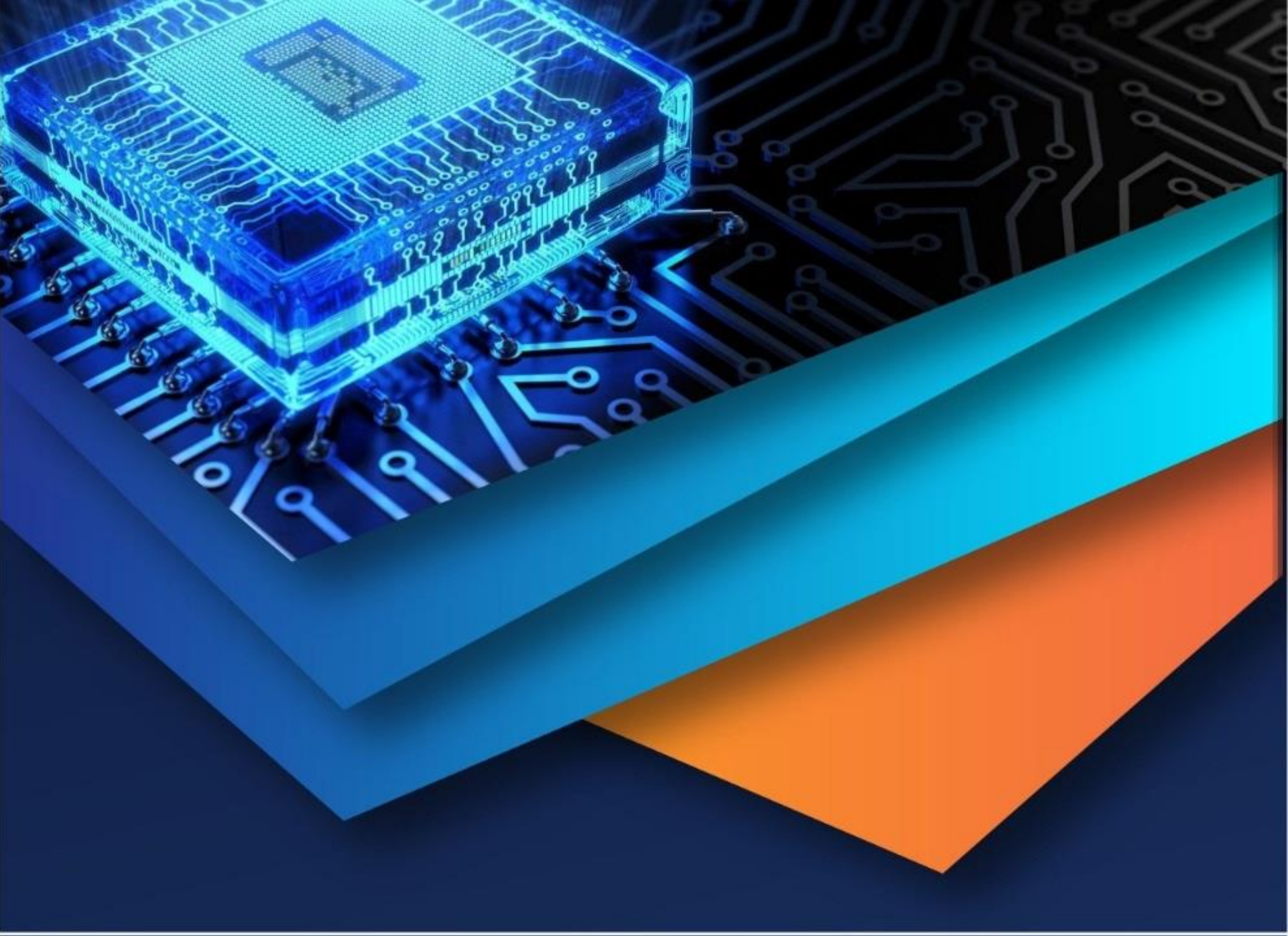
REFERENCES

[1] Turner, L.K. and Collins, F.G. (2013). "Carbon dioxide equivalent (CO_2^{-e}) emissions: A comparison between geopolymer and OPC concrete." Constr. Build. Mater., 43, 125-130.
[2] Nabeel, A.F., Neaz, S.M. and Muhammad, N.S.H. (2019). "Investigation of engineering properties of normal and high strength fly ash based geopolymer and alkali-activated slag concrete compared to ordinary Portland cement concrete." Constr. Build. Mater., 196, 26-42.
[3] Mithun, B.M. and Narasimhan, M.C. (2016). "Performance of alkali activated slag concrete mixes incorporating copper slag as fine aggregate." J. of Cleaner Prod., 112 (Part 1), 837-844.
[4] Palankar, N., Ravi Shankar, A.U. and Mithun, B.M. (2016). "Durability studies on eco-friendly concrete mixes incorporating steel slag as coarse aggregates." J. of Cleaner Prod., 129, 437-448.
[5] Unger, T.W. and Beckmann, M. (1992). "Salt slag processing for recycling, light metals." in: E.R.Cutshall (Ed.) TMS Annual Meeting San Diego California, 1159-1162.
[6] Elinwa, A.U. and Mbadike, E. (2011). "The use of aluminium waste for concrete production." J. Asian Architecture Building Engineering, 10(1), 217–220.
[7] Girsh, M., Raghavendra, S.N., Sreedhara, B.M., Manu, D.S., Hiremath, P. and Jayakesh, K. (2016). "Investigation of concrete produced using recycled Al dross for hot weather concreting conditions." REFFIT, 2, 68-80.
[8] Panditharadhya, B.J., Vargala Sampath, Raviraj, H., Mulangi and Ravi Shankar, A.U. (2018). "Mechanical properties of pavement quality concrete with secondary aluminium dross as partial replacement for Ordinary Portland Cement." IOP Conf. Ser.: Mater. Sci. Eng., 431, 032011.
[9] Panditharadhya, B.J., Raviraj, H., Mulangi, Ravi Shankar, A.U. and Amulya, S. (2019). "Performance of concrete mix with secondary aluminium dross as a partial replacement for Portland Pozzolana Cement." ASCE Library – Airfield and Highway Pavements 2019, 408-416.
[10] Adeosun, S.O., Usman, M.A., Ayoola, W.A. and Sekunowo, I.O. (2012). "Evaluation of the mechanical properties of polypropylene-aluminium-dross composites." ISRN Polymer Science.
[11] Ewais, E., Khalil, N., Amin, M., Ahmed, Y. and Barakat, M. (2009). "Utilization of aluminium sludge and aluminium slag (dross) for the manufacture of calcium aluminate cement." Ceram. Int., 35(8), 3381–3388.
[12] Petravratzi, E. and Wilson, S.A. (2007). "Case study - Residues from AD recycling in cement." WRT, 177/WR0115, 1-8.
[13] Shriraksha, J., Chandrashekar, A.R., Sujay, R.N., Manu, D.S., Parameshwar, H., Preethi, H.G. and Vinod, K.N. (2017). "Eco-concrete for sustainability: utilizing Al dross and iron slag as partial replacement materials." Clean Technical Environmental Policy, 19(9), 2291-2304.
[14] IS: 12269 – 2013. "Specifications for 53 grade Ordinary Portland Cement." Bureau of Indian Standards, New Delhi, India.
[15] IS: 4031 (Part IV) – 1988. "Methods of physical test for hydraulic cement – Determination of consistency of standard cement paste." Bureau of Indian Standards, New Delhi, India.
[16] IS: 4031 (Part V) – 1988. "Methods of physical tests for hydraulic cement – Determination of initial and final setting times." Bureau of Indian Standards, New Delhi, India.
[17] IS: 4031 (Part VI) – 1988. "Methods of physical tests for hydraulic cement – Determination of compressive strength of hydraulic cement (other than masonry cement)." Bureau of Indian Standards, New Delhi, India.

[18] IS: 2386 (Part I) – 1963. “Methods of test for Aggregates for Concrete – Particle Size and Shape.” Bureau of Indian Standards, New Delhi, India.
[19] IS: 2386 (Part III) – 1963. “Methods of tests for Aggregates for Concrete – Specific Gravity, Density, Voids and Bulking.” Bureau of Indian Standards, New Delhi, India.
[20] IS: 2386 (Part IV) – 1963. “Methods of tests for Aggregates for Concrete – Mechanical Properties.” Bureau of Indian Standards, New Delhi, India.
[21] IS: 383 – 2016. “Specifications for Fine and Coarse Aggregates.” Bureau of Indian Standards, New Delhi, India.
[22] IS: 8142 – 1976. “Method of test for determining setting time of concrete by penetration resistance.” Bureau of Indian Standards, New Delhi, India.
[23] IS: 1199 – 1959. “Methods of Sampling and Analysis of Concrete.” Bureau of Indian Standards, New Delhi, India.
[24] IS: 10262 – 2019. “Concrete Mix Proportioning – Guidelines.” Bureau of Indian Standards, New Delhi, India.



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