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PRELIMINARY STUDIES ON SELF COMPACTING GEO-POLYMER CONCRETE USING WASTE FOUNDRY SAND.

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Abstract: *Preparation of Self compacting geo-polymer concrete (SCGC) is a movement towards preparation of innovative sustainable concreting techniques in construction industries that compact due to its self weight and it don't required cement too . This method is quite expensive at initial stage but reduces the labour expenses and this is also environment friendly because low emission of CO_2 gases which is released in huge amount from the concrete formed of OPC. The preset investigation is mainly focused on the preliminary studies of SCGC on varying molarity of NaOH and replacing the river sand with waste foundry sand. Using waste foundry sand in place of river sand solves the problems of river mining and also solves the problems of disposal of waste foundry sand. Studies reveals that increasing the molarity of NaOH decreases the fresh properties but increased the compressive strength of SCGC.*

Keywords: *self-compacting geopolymer concrete, Fly Ash, ground granulated blast furnace slag, waste foundry sand, and normality of NaOH solution.*

I. INTRODUCTION

Concrete is the key material in construction industries. Ordinary Portland cement is key ingredient in concrete sometimes Pozzolana Portland cement is also used in place of OPC. The concrete construction practice in use is considered as unsustainable because it consumes a huge quantity of sand, stone and water and 2.5 billion tones of OPC per year.

Considering its effect on ecology, production of OPC is harmful to ecology as it consumes large amount of natural resources and releases a great amount of green house gases. Davidovits proposed that an alkaline liquid could be used to react with the silicon (Si) and Aluminum (Al) in a source material of geological origin or in by-products materials such as Fly Ash (FA) and Rice Husk (RHA) to produce binders [1]. The two main constituents of geopolymers, namely the source materials and the alkaline liquids [1]. This could be natural mineral such as kaolinite, clays etc. Alternatively, by-products such as fly ash, silica fume, slag, rice husk, GGBS, red mud etc[1]. The material used as geo-polymer binders should be rich in silicon (Si) and Aluminium (Al). Both Fly Ash and GGBS in certain proportion were found to be geopolymer source materials to obtain sufficient strengths of geopolymer concrete [2]. Alkaline liquids are from soluble alkali metals that are usually sodium or potassium based[1]. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide(NaOH) or Potassium Hydroxide (KOH) and Sodium Silicate or potassium silicate. Many of the GPC mixes earlier tested required the use of high temperature curing. Heat curing substantially assists the chemical reaction that occurs in the geo-polymer paste[1]. Both curing time and curing temperature influence the compressive strength of geopolymer concrete [1]. However recent studies revealed that GPC mixes can be developed for ambient room temperature [5]. It was noticed that fresh GPC was highly viscous with low workability and hence, super plasticizer (SP) was found to be used to attain adequate workability [2]. On increasing the concentration of NaOH and curing temperature compressive strength of geopolymer concrete increases. On increasing the molarity of NaOH more than 14M the compressive strength reduces [2].

Fresh self compacting geopolymer concrete has the follow properties: higher slump flow, high viscosity, passing ability and resistance to segregation[3].The benefit of self compacting geopolymer concrete(SCGC) over conventional concrete(CC) is that it is eco-friendly and doesn't required compaction at all. Using waste foundry sand as replacement of sand is economical and saves natural resources. To sustain the environment from sand mining in rivers, waste foundry sand is used. It is found from studies as the quantity of waste foundry sand increases the split tensile strength of concrete decreases. This self compacting geopolymer concrete is highly beneficial in congested reinforced structure and as cement is not used it will be also environment friendly. Studies reveals that the compressive strength of SCGC increases when thermal cured at 60-70 ^{0}C, but it decreases when temperature exceeds 70^{0}C[7].It is found that on increasing molarity of NaOH the fresh properties of concrete decreases [6].

In metal industries for various process in metal casting foundry sand is used. After the casting of metal the burnt fine grained foundry sand can be re-used for various purposes in construction industry. It will reduce the cost of construction. But split tensile strength decreases on increasing the percentage of waste foundry sand[4].

In the present research we examined how self compacting geopolymer concrete using waste foundry sand as replacement is good over conventional concrete. Acceptance criteria for its fresh properties, materials used, Acceptance criteria for test to be conducted for its fresh properties such as slump flow, T_{50cm} , V-funnel and L-box as per EFNARC [10]. Test were performed such as slump flow, T_{50cm}, V-funnel and L-box were conducted to assess the fresh properties.

II. EXPERIMENTAL MATERIALS

2.1 Fly Ash

Nowadays fly ash is the material which is most extensively used in construction industry as a partial replacement of cement. The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 7% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime mixed with water to react and produce cementitious compounds. Alternatively, adding a chemical activator such as sodium silicate (water glass) to a Class F ash can form a geopolymer .We are using class F fly ash obtained from "Wanakbori Thermal Power Station, Gujarat, India".

2.2 Ground granulated geopolymer concrete(GGBS)

It is obtained as a by-product of iron and steel-making from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. It is used as a partial replacement of cement, when it is used in certain proportion with fly ash it significantly helps in increasing the compressive strength. The main components of blast furnace slag are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1-18%). In general increasing the CaO content of the slag results in raised slag basicity and an increase in compressive strength.

2.3 Waste Foundry Sand

Mostly metal industries prefer sand casting system. In this system mould made of uniform size and uniform sand with high silica content is used. After the casting of metal foundries reuse and recycle the sand but after several time of using it the sand is discarded and it is called waste foundry sand. Its use in construction industry is economical and also solve the problems of its disposal.

2.4 Ordinary sand

Aggregate contains almost 75-80% of the concrete volume. While in SCGC for self compaction the fine aggregate content should be 40% of the mortar volume. Ordinary sand which pass through 4.75mm IS sieve and having no more than 5% coarser material are included in fine aggregate. River sand is obtained by river mining which is a non-renewable source .fine aggregate fills the voids and increases the workability of concrete.

2.5 Coarse aggregate

The aggregate having size more than 4.75mm is termed as coarse aggregate. In order to achieve self compactibility and passability of concrete through congested reinforcement coarse aggregate of two different sizes are used in SCGC. In SCGC the coarse aggregate content is 50% of the solid volume and coarse aggregate in two different size at 60:40 ratio can be used.

2.6 Alkaline activators

Generally sodium hydroxide or potassium hydroxide and sodium or potassium silicate is used as alkaline activators for formation of C-S-H gel. Studies reveals that only using sodium hydroxide or sodium silicate is not much effective. So combination of sodium hydroxide and sodium silicate is used generally. Sodium hydroxide pellets is 97-8% purity is generally used and sodium silicate with Na_2O = 13.7% , SiO_2 = 29.4% and water = 55.9% is generally used. With the increase in concentration of solution in terms of molarity (M) the concrete becomes brittle with increased compressive strength. Cost of sodium hydroxide solids is high and preparation is very caustic. Generally sodium silicate-to-sodium hydroxide ratio of 2 to 2.5 is maintained in concrete casting which will help in gaining the strength after 24h of casting.

2.7 Water

Water plays an important role in concrete while in self compacting geopolymer concrete water does not play any important role in gaining strength rather it helps in improving the workability. As studies reveals that geopolymer mix is less workable so to attain self compactability extra water is needed to add in the mix.

2.8 Super plasticizer and viscosity modifying agent

Self compacting concrete can be prepared by compounding admixture with high efficiency water reducing agent. According to requirement of performance of SCGC , climate conditions and the construction technology , combined with concrete raw materials performance, adaptability to cement and mix proportion and other factors, the species and dosage of admixture can be determined through the test.

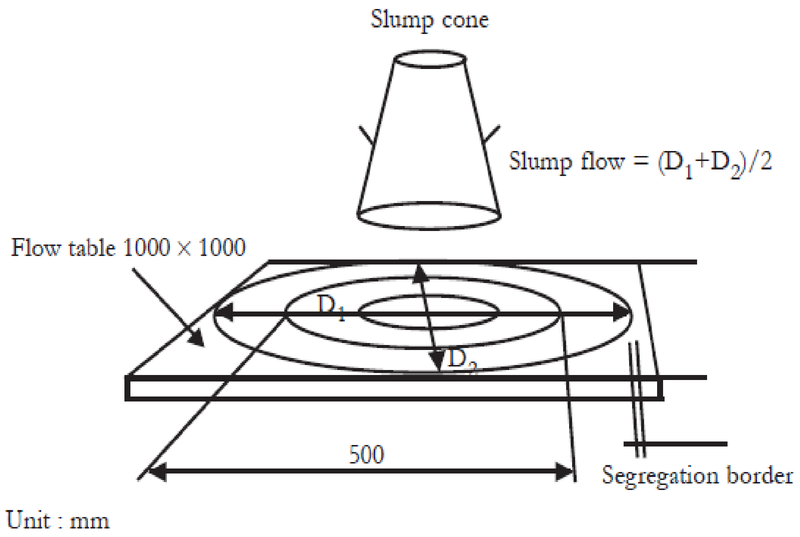
III. TEST PERFORMED ON FRESH SELF COMPACTING GEOPOLYMER CONCRETE.

3.1 Slump Flow test

Slump flow gives an assessment of horizontal free spread (flow) of self-compacting concrete without obstacles. The method was developed in Japan from the well-known Abram's cone slump method.

3.1.1 Equipment:

Metal cone 300 mm high, base 200 mm in diameter, top opening 100 mm in diameter. A rigid square plate measuring 700 - 1000 mm, with a marked centre of the cone and a circle 500 mm in diameter.



SLUMP FLOW TEST

3.1.2 Procedure and basic measuring values:

The cone is placed on the board, filled with concrete and then raised. Instead of measuring the settlement of concrete in the cone, the diameter of concrete circle SF = d is measured when the fresh concrete mass stops flowing. Slump flow is calculated as the average value of two measured diameters perpendicular to each other: SF = (dm + dr) /2.

This is a fast, simple method which is most frequently used both in laboratories and in construction sites. It gives a good assessment of deformability (flowability of fresh concrete) and can give visual information on stability. It does not give any information on passing ability of fresh concrete. Acceptance criteria of slump flow for self compacting geopolymer concrete. It is necessary and obligatory to define the slump flow class, SF, as the basic SF1 can be applied in:- Slightly or non- reinforced concrete structures that are cast from the top with free spread from the delivery point (for example, floor structure slabs), - Pumped concretes,- Sections of structures that are sufficiently small to prevent larger horizontal flow (piles and some sections of foundations). SF2 can be applied in majority of normal structures (walls and columns). SF3 is usually applied in concrete with maximal aggregate grain size less than 16 mm, in elements with congested reinforcement, in structures with complex shapes of forms, if the forms are filled from below. SF3 class gives better surface finish than SF2 when the fresh concrete is placed normally vertically but the risks of segregation are higher.

Concrete class	Slump flow (mm) specified	Confirmation of required spread criterion
SF1	550 – 650	520mm ≤ d_m ≤ 700mm
SF2	660 – 750	640mm ≤ d_m ≤ 800mm
SF3	760 – 850	740mm ≤ d_m ≤ 900mm
Stated value of spread concrete diameter	d_m	d_m ± 80 mm

Acceptance criteria for Slump flow test for self compacting geopolymer concrete.

In special cases self-compacting concretes with flow diameter greater than 850 mm can be required but then special care should be taken of control of all forms of segregation. In that case maximum grain of coarse aggregate should be less than 12 mm.

3.2 V-funnel test and V-funnel test at $T_{5\ minutes}$

3.2.1 Introduction

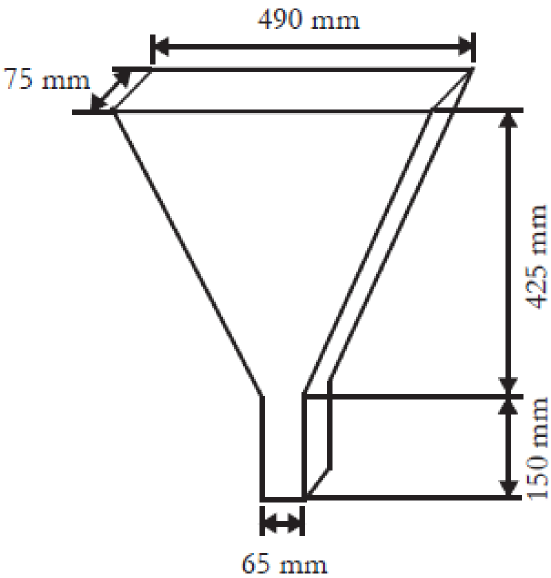
The test was developed in Japan and used Ozawa et al. The equipment consists of a V-shaped tunnel, shown in fig. An alternative type of V-funnel, the O funnel, with a circular section is also used in Japan. The described V-funnel test is used to determine the filling ability (flow ability) of the concrete with a maximum aggregate size of 20mm.The funnel is filled with about 12 liter of concrete and the time taken for it to flow through the apparatus measured. After this the funnel can be refilled concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increase significantly.

3.2.2 Assessment of test

Though the test is designed to measure flow ability, the result is affected by concrete properties other than flow. The inverted cone shape will cause any liability of the concrete to block to be reflected in the result – if, for example there is too much coarse aggregate. High flow time can also be associated with low deformability due to high paste viscosity, and with high inter-particle friction. While the apparatus is simple, the effect of the angle of the funnel and the wall effect on the flow of concrete are not clear.

3.2.3 Equipment

- V-funnel
- Bucket (+/- 12 liter)
- Trowel
- Scoop
- Stopwatch



V-funnel test apparatus

3.2.4 Procedure of flow time.

- About 12 liter of concrete is needed to perform the test, sampled normally.
- Set the V-funnel on firm ground.
- Moisten the inside surfaces of the funnel.
- Keep the trap door open to allow any surplus water to drain.
- Close the trap door and place a bucket underneath.
- Fill the apparatus completely with concrete without compacting or tamping; simply strike off the concrete level with the top with the trowel.
- Open within 10 sec after filling the trap door and allow the concrete to flow out under gravity.
- Start the stopwatch when the trap door is opened, and record the time for the discharge to complete (the flow time). This is taken to be when light is seen from above through the funnel.
- The whole test has to be performed within 5 minutes.

3.2.5 Procedure for flow time at T5 minutes

- Do not clean or moisten the inside surfaces of the funnel again.
- Close the trap door and refill the v-funnel immediately after measuring the flow time.
- Place a bucket underneath.
- Fill the apparatus completely with concrete without compacting or tapping, simply strike off the concrete level with the top with the trowel.
- Open the trap door 5 minutes after the second fill of the funnel and allow the concrete to flow out under gravity.
- Simultaneously start the stopwatch when the trap door is opened and record the time for the discharge to complete (the flow time T5minutes).
- This is taken to be when light is seen from above through the funnel.

Concrete class	T_{500} (s) , specified time of concrete flow to d_m = 500 mm,	Corresponding time of V-funnel emptying t_v (s)	Confirmation of required criterion (for emptying time of V-funnel (s))
VS1 / VF1	$t \leq 2$	$t \leq 8$	$t \leq 10$
VS2 / VF2	$2 < t$	$8 < t \leq 25$	$7 < t \leq 27$
Target time for V-funnel emptying			$t - 3 \leq t \leq t + 3$

Acceptance criteria of V-funnel test for self compacting geopolymer concrete

3.3 L-box test method

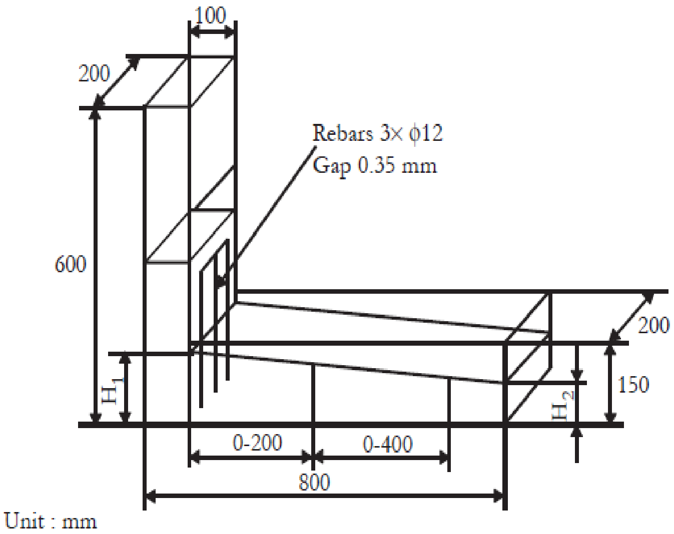
This method, based on Japanese designs for underwater reinforced concrete structures, was described later (Petersson Ö. Et al. (1996). It is used as a primary method in testing passing ability of concrete through congested reinforcement (The European Guidelines for SCC, 2005).

3.3.1 Assessment of test

This is widely is used test, suitable for laboratory, and perhaps site use. It assesses filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section. Unfortunately there is no agreement on materials, dimensions, or reinforcing bar arrangement, so it is difficult to compare test results. There is no evidence of what effect the wall of the apparatus and the consequent 'wall effect' might have on concrete flow, but this arrangement does, to some extent, replicate what happens to concrete on site when it is confined within formwork. Two operators are required if times are measured, and a degree of operator error is inevitable.

3.3.2 Equipment

L box of a stiff non absorbing material, Trowel, Scoop, Stop watch.



L-box apparatus

3.3.3 Procedure

- About 14 liter of concrete is needed to perform the test, sampled normally.
- Set the apparatus level on firm ground, ensure that the sliding gate can open freely and close it.
- Moisten the inside surfaces of the apparatus, remove any surplus water
- Fill the vertical section of the apparatus with the concrete sample.
- Leave it to stand for 1 minute.
- Lift the sliding gate and allow the concrete to flow out into the horizontal section.
- Simultaneously, start the stopwatch and record the times taken for the concrete to reach the 200 and 400 mm marks.
- When the concrete stops flowing, the distance “H1” and “H2” are measured.
- Calculate H2/H1, the Blocking Ratio (PA=H2/H1)
- The whole test has to be performed within 5 minutes.

Concrete class	**Passing ability**	**Confirmation of the required criterion (for passing ability PA)**
PA1	$0.8 \le PA$ with obstacle with 2 rebars	$0.75 \le PA$
PA2	$0.8 \le PA$ with obstacle with 3 rebars	$0.75 \le PA$
specially defined passing ability of L-box		not less than 0.05 below specified value of PA

Acceptance criteria for L-box test for self compacting geopolymer concrete.

3.4 T_{50} test

A test method for evaluating the material segregation resistance of SCC, where the 500-mm flow reach time is measured in the slump flow test above, that is, the time for the flow to reach 500 mm is measured in the slump flow test. SCC should give T50 = 2-5 seconds.

IV. SCOPE OF STUDY

Despite of its advantages and versatile nature, SCGC has not gained much popularity in construction industry, though it has been widely promoted in the countries like Australia. Awareness of SCGC has spread across the world , promoted by concerns with green house gas emission , poor consolidation and durability in case of conventionally vibrated concrete.

Some researchers have developed SCGC with different values of molarity and also considered the limited content of coarse aggregate and more content of fine aggregate. Keeping this in view, the present investigation is taken up to study the effect of replacing river sand with waste foundry sand in order to achieve low cost concrete with different material. In the present work , fly ash and ground granulated blast furnace slag (50:50) ratio is taken as filler material in SCGC mix.

V. CONCLUSION

- It is environment friendly as emission of greenhouse gases is prevented by using geopolymer binders in place of cement.
- Problems for disposal of fly ash and ground granulated blast furnace slag is solved.
- Special curing conditions is required as on curing this concrete at 60-70^{0}C gives higher compressive strength.
- Use of waste foundry sand as replacement of river sand will be helpful in preventing river mining.
- It will solve the problems of disposal of waste foundry sand.
- The mix designed with lower size of aggregate yields better fresh properties.
- The cost of labour for compacting the concrete is eliminated.
- On increasing the molarity of NaOH the concrete become brittle with increased strength.
- Replacing river sand with waste foundry sand increases compressive strength but decreases split tensile strength.
- This type of concreting is most suitable in formation of precast structural members as curing temperature can be maintained in laboratory.

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