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High strength grouting material from recycled rUSP resin for mine support system

Anchoring of the rock bolt plays a significant role when deformation or movement of the layers in the rock mass induces axial tensile load in the installed rock bolts. In this situation, low anchorage strength can be the potential cause for the bolt failure in mine, leading to rockfall. Bolts will fail if the induced axial load to the bolt is more than the anchorage strength. Anchorage strength depends on so many factors such as kind of bolt, grouting media, annular space, and shear behaviour at the bolt grout interface, surface profile, installation mechanism and position. The difficulty of the support systemis governed by on the load transmission mechanisms between the rock, the bolt and the resin. Polyethylene terephthalate (PET) is separated from the multilayer packaging film waste and converted into unsaturated polyester resin. The rUSP resin was used for the preparation of high strength grouting material, studied for their efficacy and physico-mechanical parameters such as gel time, reaction temperature and compressive strength and compared to virgin resin. It is found that physico-mechanical parameters of grouting material prepared from rUSP were better than virgin resin-based grouting material. The conclusions of research will improve the effectiveness of maintenance and decrease the expenses connected with the manufacturing of resin capsule.

Keywords: *rUSP resin, anchorage pullout test, activator.*

Introduction

Anchorage pullout test also is known as short encapsulation pullout test. Encapsulation failure is the process of failure for totally grouted bolts. As roof distortion mechanism its approach is up-ward, the bolts can become deeply loaded close their upper tops. If the given pressure increases or surpasses the anchorage, the bolts will pull out. This kind of anchorage failure is almost certainty when the roof floor is weak, where roof support is most precarious. The primary roof supports were used full column filled bolts contain more than 80% in US coal mines (Mark et al., 2002). About 3,000 MSHA reportable, non-danger roof falls happen each year, and the majority of them are attributed to bolt system failure (MSHA Injury Report, 2011-2015). Design of a roof bolting system and roof control plans involve knowledge of weight carrying capability of the screw (bolt) and stiffness characteristics of the bolt anchorage system. During set up, the turning of the rock bolt combines the constituents of the resin capsules. When the constituents of resin capsule are combined properly, the resin will establish and grip the rockbolt in the support hole, resulting in an operative anchorage (Barrett, 2006).

Grouted bolt characteristics are measured through anchorage pullout test in the field where a bolt is anchored at a preferred horizon above the coal seam with only about 0.3 m of grout length (Mark et al., 2001). The length of the encapsulation is grounded on the bolt and host rock characteristics with the goal that bolt anchorage will fail before to reaching a weight carrying capacity of the bolt (Mark et al., 2000). The grip factor designates the weight carrying capability of the bolt while the load-deformation behaviour or anchorage stiffness (AS) characterizes the reinforcement potential of rock bolt (Mark, 2000). The design of several mines, quarry interferes the inventive stress state in the Earth's crust. This consequence in pressure concentrations that effect by the constancy of the rock physique nearby the diggings. It is necessary to convert the inner behaviour of the rock mass nearby diggings in order to strengthen the ground and alleviate diggings. Rock bolts (resin grouted) are broadly used for excavation methods. The rock-bolt applies a bonding force and a clamping force that retains the rock mass composed when roof bolt effectively installed. This upsurges the cohesive strength of all gaps in the rock and improves the constancy of the diggings (Esterhuizen, 2014).

The high strength grouting material is used in the areas for stabilizing such as an underground mine support system, tunnelling, road and bridges, geotechnical related work, waste leakage and management and civil engineering works.

This paper describes the application of rUSP resin in preparation of high strength grouting material suitable for an

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TABLE 1: PHYSICO-CHEMICAL PROPERTIES OF rUSP AND VIRGIN RESIN

	Reaction Initiator (%)	rUSP resin					Virgin Resin				
		Acid No. (mgKOH/g)	Viscosity (cps)	IGT (Min.)	FST (Min.)	Temp. (^oC)	Acid No. (mgKOH/g)	Viscosity (cps)	IGT (Min.)	FST (Min.)	Temp. (^oC)
1.	0.1	6.0	350.0	8.0	6.0	55.0	10.0	500.0	10.0	7.0	70.0
2.	0.2	5.8	380.0	7.5	5.5	56.5	9.5	506.0	9.5	6.8	77.0
3.	0.3	5.2	399.0	6.8	4.5	58.5	8.9	515.0	8.8	6.0	81.0
4.	0.4	5.0	450.0	5.5	3.8	60.5	8.2	521.0	7.4	5.6	95.0
5.	0.5	4.8	510.0	4.8	2.6	63.9	7.5	526.0	6.8	4.2	101.0
6.	0.6	4.3	550.0	3.0	1.0	65.0	6.0	530.0	5.5	3.0	105.0

Note: IGT=Initial Gel Set Time; FST= Final Set Time

TABLE 2: ANCHORAGE PULLOUT TEST OF RESIN GROUTING MATERIALS

Time		Anchoragepullout test of resin grouting material (tonnes), as per DGMS Cir. No.4, 2013	Anchoragepullout test of virgin USP resin grouting material (tonnes)	Anchoragepullout test of rUSP resin grouting material (tonnes)
1	15 min	-	8	10
2	30 min	12	15	17
3	1 hrs.	-	22	24
4	8 hrs.	15	25	28
5	24 hrs.	24	32	34.5

underground support system and also describe the physical and chemical parameter and comparison of performance with a virgin resin-based grouting material.

EXPERIMENTATION

The rUSP resin-based grouting material having different types of fillers was formulated and prepared. High strength grouting material preparation comprises the following steps:

Step-I

The double chamber poly tube is cut according to the desired size. The desired size of the poly tube is always kept 5 cm more from the desired length for better crimping of the ends. The bottom of the poly tube was crimped with 2 mm aluminium wire from one end.

Step-II

The catalyst is filled in such a way that no leakage of the paste catalyst is observed during the filling of the resin matrix in double chamber polytube.

Step-III

- The required amount of the fillers, such as barytes and feldspar, are taken in the mixing blender and added the rUSP resin by required weight and add the reaction initiator.
- Start the blending along with resin-filler and reaction initiator at the speed of 60-100 RPM till consistency achieves in thematrix.
- The matrix was tested for initial setting time, final setting time, reaction temperature before preparing the cartridges. Cast the mould in 50×50mm size and measure the compressive strength using Universal Compression Testing Machine (Fig.4). Results of gel and set time, acid no., viscosity and the reaction temperature are shown in Table 1.The compressive strength of the high strength grouting material determined by using UTM and results are shown in Table 2.
- Resin matrix was filled in the inner chamber and catalyst was filled in the outer chamber of the polytube with the help of pneumatic filling and sealing machine.

Step-IV

- Filled poly tubes (rUSP resin matrix and paste catalyst) were crimped another end with the help of aluminium wire. Resin grouting cartridges were cleaned with wood dust and packaging in the CC box with insulating material.

Fig.1(A-E), shows the manufacturing steps of rUSP based resin grouting product suitable for mining application. Fig.2 shows the process flow chart of preparation of rUSP resin-based grouting material and also made of cartridges. Fig.3(A-J) shows the steps for determining the strength of the grouting material using anchorage pullout test methods. anchorage pullout test results are shown in Table 2.

Results and discussion

The result is shown in Table 1 for physical and chemical properties of rUSP resin and comparison with virgin unsaturated polyester resin. The results indicated that the gel and final setting time of rUSP resin were 8 minutes at 0.1% reaction activator and 3 minutes at 0.6% of reaction activator.

Fig.1 Preparation of high strength grouting material for roof support in underground mining in the lab. (A) Polytube cutting for required length, (B) Blender unit for mixing of filler and resin, (C) Catalyst filled in double chamber polytube, (D) Resin matrix filled in another chamber of double chamber polytube, (E) Prepared resin capsule for roof bolting in an underground mine

For virgin polyester resin, it was 10 minutes and 5.5 minutes for the same % of reaction activator. The final setting time of rUSP was 6 minutes and 1.0 minutes at 0.1% and 0.6% reaction activator, and it was 7 minutes and 3 minutes for virgin resin at the same amount of reaction activator. Acid no. of rUSP and virgin resin were found 4.3-6 mgKOH/g and 6-10 mgKOH/g respectively upon varying reaction activator from 0.1% to 0.6%. The reaction temperature of virgin resin was found from 70ºC at 0.1% reaction initiator, upon increasing of reaction initiator from 0.1 to 0.6%, the temperature increased from 70 to 105ºC for virgin USP resin, and it was increased from 55 to 65ºC for rUSP resin.The reaction temperature of rUSP resin was found below 70ºC at 0.1% reaction initiator and found suitable for manufacturing grouting material.

The compressive strength of polymer mortar was evaluated based on compression testing of specimens. Three specimens (50mm×50mm) each of the optimal sets were prepared. The specimens were tested under direct compression using a 200-tonnes compression testing machine shown in Fig.4.

The compressive strength for grouting material mould with increasing the amount of activator 0.1, 0.25, 0.50, 0.75 and 1.0% respectively, are shown in Fig.5. It is a significant decrease in CS upon increasing of activator. Results indicated that 0.1% w/w of the activator was found suitable to initiate the reaction.

The results are shown in Table 2 and Fig.6, indicated that the compressive strength of moulds prepared with virgin USP resin was less than rUSP resin. It was 8 tonnes, after 15 minutes and 32 tonnes after 24 hrs. respectively after casting of moulds for virgin USP resin. Compressive strength of grouting material prepared from the recycled unsaturated polyester (rUSP) resin was 10 tonnes and 34.5 after 15 minutes and 24 hrs. respectively.

Conclusions

High strength grouting is accomplished in order to attain enhancement of physico-mechanical characteristics of the soil and rock. It contains practice and complex acquaintance from numerous fields like structural geology, mining, geology, hydrogeology, underground constructions soil and rock

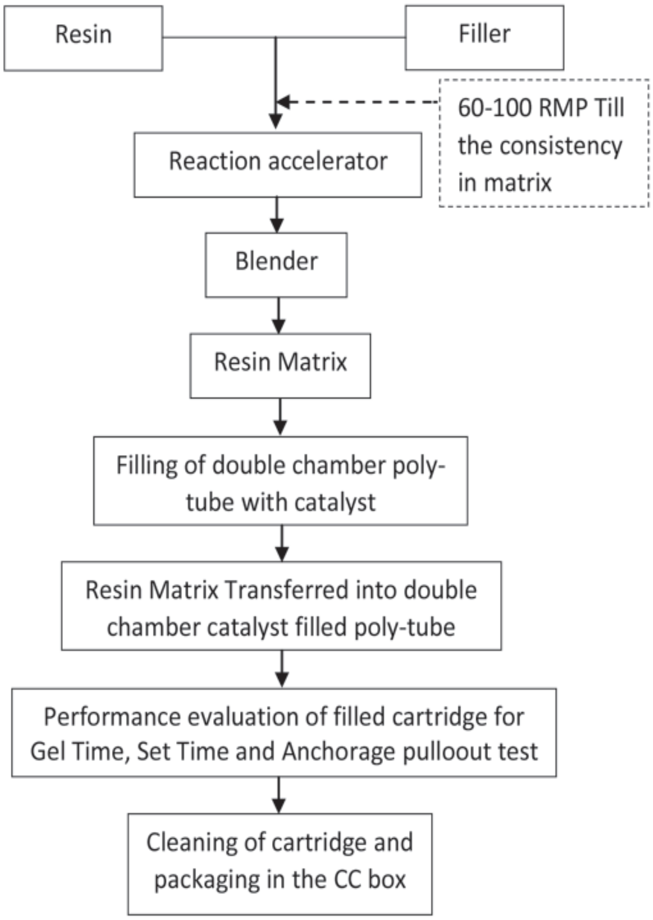

Fig.2 Process flows chart for preparation of rUSP based grouting material

mechanics, defects of constructions and their repair, geo-technics, structural stability, the chemistry of the grouting material and grouting technique (pumps, packers) etc. High strength grouting materials exemplify an active process of solving of numerous types of difficulties in geo-technics, building construction industry and most valuable for mining practices to civil engineering and geotechnics such as crack filling, roof support system, instant leakage repair and other construction materials etc. The following conclusions are made based on experimental results:

i. The formulation prepared by rUSP takes 3% less resin w/w to achieve proper consistency of the matrix in comparison with virgin USP resin and found coast effective in comparison with virgin resin. It is due to the lower viscosity of the rUSP resin.

ii. Upon increasing of reaction activator, compressive strength decreases and 0.1% w/w of resin was found suitable for preparation of high strength grouting material, and also found the optimum for initiating the polymerization reaction.

iii. Compressive strength of grouting material prepared by using rUSP is better than virgin resin.

iv. Upon increasing of activator, the reaction temperature is also increased, which is detrimental to polymerization reaction, and CS will be affected due to an increase in reaction temperature.

v. rUSP resin is found suitable and cost-effective to produce high strength grouting material.

Fig.3 Anchorage pull out test in laboratory (A to J)

Fig.4 Universal compressive strength testing machine

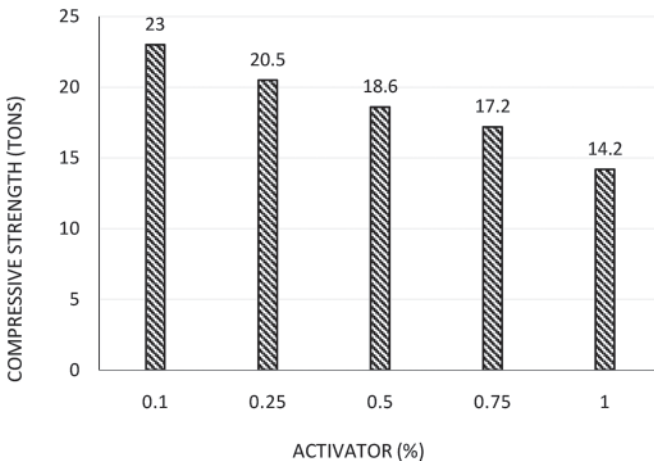

Fig.5. Effect of reaction activator on compressive strength

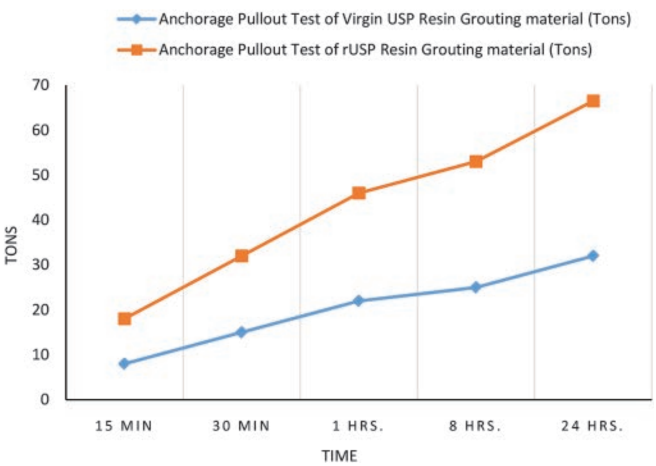

Fig.6. Anchorage pullout est with different time duration

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