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Research paper

Recycling Waste into Composites: A Review of Sustainable Approaches & Material Innovations

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Abstract

The main objective of this work is to solve the issues of plastic waste management (PWM) in developing countries by designing a shredding machine. The designed machine involves a drive shaft, shredding blade, casing, hopper assembly. Moreover, the shape of plastics is very different from their equivalents while it is used in large-scale mass recycling, energy difference recycling highlights the environmental benefit of using plastics, where the SM may indicate a potential function for recycling purposes. Also the machine and composites are optimized to find better material for both shredder and wastage. Shredder machine is developed by assembling all manufactured parts which can shred 1 Kg plastic, Wood, Glass and Aluminium at once. Also testing of innovative machine by means of crush particles produced from wastages to recycle it is done. Experimental validation of main components is needed for finding stress & deformation also application of the optimization solution by finding better suitable material for different components of shredder to withstand under several operating conditions. Final composite products from wastage also optimized and better suitable material finding out is done. The main objective of the papers is testing of innovative machine by means of crush particles produced from wastages to recycle it and Experimental validation of main component in ANSYS by finding stress & deformation. Applying the optimization solution by finding better suitable material for different components of shredder to withstand under several operating conditions. Work methodology depends upon the type of wastages to make composites and better suitable material for the shredder components to sustain under the heavy operating conditions.

Keywords: *Waste Recycling, Shredding Machine, crush waste, Plastic waste Management, Composites.*

1. Introduction

Normally, the peoples always produce waste in all kinds of things and that is disposed of using many ways, thus Waste Solid Management (WSM) is most common issue for world. The quantity of produced waste, disposal technique, people values, and perceptions are changed. Nowadays, the use of plastics, applications and composites are increased because of its benefits like simple manufacturing process, and low cost. Thus, the accumulation of large amounts of waste plastic poses great challenges for their disposal. This type of invention is triggered by concerns about mixed waste worldwide. Despite the evolving hybrid recycle technology, environment considerations, especially the process requirement of recycling systems (RS), have been fully targeted. The research targets to design the energy requirements of hybrid recycle method by considering quality characteristics of recycled material Consequences include establishing efficient use of energy demand and evaluating the circular economy for composite materials. Also, plastic waste is one of the solid wastes and the polyethylene terephthalate (PET) material is one of its parts that can be used for developing glass and plastic products, bottles, etc. The utilization of Polyethylene Terephthalates can develop bottles that are transparent and employed to pack liquids like soda, water and soon. These things are non-biodegradable and may remain unchanged on earth for up to 4500 years posing a threat to our streams, lands, drainage systems, and so on. Moreover, in India more than 20 percentage plastic wastes are in the MSW. Also this issue is not only for our country that is the problem around the total world. [4] According to the report in 1950, the consumption of plastic products around the world is continuously increased from the amount of 5 million tons to a hundred million tons. Therefore, plastic waste production is increased as 20 times higher than the amount of plastic produced in 50 years ago. It demonstrates the use of plastic things is increased day by day that creates a large amount of wastes. As global warming continues to increase as a result of global warming and the unavailability of benign drinking water in the rural as well as urban places in India, the growing population is pushing for a steady request for the bottled water. Subsequently, there are public water systems in some areas and the supply channels are not reliable for providing pure drinking water.[13] Nowadays, most of the peoples have its private boreholes for drinking water, but the refining system is very poor. Also, the economic incentive is available for recovering the carbon fiber to perform the recycling process, but the biggest issue is reducing the quantity of plastic waste. So, the contradictory concessions pose to have a serious issue for developing and performing the recycling process. [8]

Normally, the shredding machine (SM) involves the crusher system via the single-axis shaft used to cut the material depends on the strengths like impacts and shear. The developed machines for performing the recycling process is very expensive, and the setup is high, so we developed SM to deal with these issues, and these machines begin to be recycled individually. The design and fabrication of this current project agreement with the SM is subject to various parameters and, moreover, production analysis is the most important aspect for the execution of this project. Also, this project is especially important in making low cost and easy-to-operate shredder machine.[22]

Fig 1: Shredder Machine

The nomenclature of the symbols used in the Here, to diminish the large size of solid wastes into smaller pieces, the new model SM is developed. The main goal of these SMs is to reduce the size of solid things and make them small particles. [3] Shredding technology is the method for aggregating the force multiplied using the mechanical property of molecular material and resisting decay than crushing material. Also these shredding materials should have high strength also the hardness than the product of plastic materials. Moreover, plastic is the material that is commonly use around the world and in this category of materials are employed as the alternative things to paper in many place because of its high proportioning, less weights, very low cost, cheaper and durability. The purpose of this work is to explore the effect of functional parameter on the process energy requirement and quality of recycling in mechanical recycling of fiberglass composite. [19]

The majority of the plastic waste on the planet today goes to landfills. PWM is quite possibly the most perplexing cycles and they are the most unproductive. At most capacities, parties, occasions, and so on, water is given in jugs of various sizes. These pre-owned containers involve an enormous removal space; typically spilling over with the dustbins gave at these areas, which regularly go to the landfill. Utilized plastic sacks, plastic sheets and containers of different sizes, shadings, and surfaces fly around uninhibitedly, dissipate in the roads, swim in pits, and represent a genuine ecological danger. These keep the climate messy and make hindrances to our sewage framework. Numerous endeavours have been made to advance plastic packs and other plastic items, however without any result because of its variety in everyday use. These days' trucks are brimming with plastic waste, particularly bottles, so mishaps cause genuine losses as Consider the possibility of crushing and pressing waste plastic materials, To lessen the truck issue, Model fiction and test [33] [21]

These kinds of mechanical shredders can likewise be extremely useful in tackling numerous security issues. Notwithstanding these applications, plastic waste shredders are likewise harmless to the ecosystem. Recorded are some valuable advantages of plastic waste shredders; these sorts of destroying machines can help decrease plastic waste and size. [13] Commonly, these kinds of hardware are accessible with over-burden security and stage disappointment insurance frameworks to guarantee safe activity. There are numerous organizations that offer plastic destroying machines that are reasonable for destroying various kinds of plastic items that give proficient and fast execution. [22] Most organizations likewise offer plastic destroying machines in tweaked sizes to suit the necessities of their clients. To guarantee sturdiness and elite, these sorts of hardware are produced using excellent crude materials. It offers a wide assortment of cutting and cutting methods. To change over these segments or scrap materials into items, these plastics arrive in an assortment of sizes and shapes; they are recovered for use in an assortment of creation methods. For this reason, you need a plastic waste shredder.[9]

2. Literature Review

Ananthi K et al. (2020) observed that people consistently produce and discard waste, making solid waste administration a persistent issue. The study highlights human perceptions of waste types, quantities, and disposal methods, which significantly influence waste management practices [1]. A. Venkata Rathnam et al. (2017) examined the configuration of a twin shaft shredder to optimize the structure, material, and approach through literature surveys. The research helps in choosing appropriate materials and modeling methods for shredder systems [2]. Abhay Katiyar et al. (2020) presented serious issues in natural waste management, highlighting issues common to developing nations such as India where the infrastructure finds it difficult to handle increasing amounts of organic waste [3]. Agbonkhese Kingsley A et al. (2020) discussed the rising need for vegetables in expanding populations and stressed the significance of waste management in agriculture because of its economic and nutritional value [4]. Alessandro Suardi et al. (2020) highlighted the under-explored potential of pruning residues from olive woodlands, which are commonly regarded as waste but would create supplementary income if managed well [5]. Briggs M. Ogunedo et al. (2020) emphasized the environmental risk of plastic waste and the importance of systematic plastic recycling policy, putting plastic recycling on the agenda of environmental waste management [6].

Chinthankumar D. M. et al. (2016) carried out experimental studies on plastics and concluded that plastics have a significant impact on environmental elements like air, water, and land due to unsystematic disposal [7]. C. C. Ugoamadi et al. (2011) created and developed a plastic recycling machine specific to efficient waste management and minimizing dependence on costly imported machinery [8]. C. S. Aitchison et al. (2005) investigated food waste as a valuable organic material with a high calorific value, frequently ignored despite its promise for composting and energy recovery [9]. Darshan R et al. (2017) introduced a plastic bottle crusher for easier and more efficient management and disposal of discarded plastic containers, enabling the recycling process [10]. E. Suneesh et al. (2017) illustrated that nano-alumina addition enhanced impact strength in materials, with the effects possibly being a result of enhanced matrix bonding and structural refinement [11]. E. Suneesh et al. (2019) also found micro-alumina enhanced compressive strength, further improving the mechanical

properties of the composite material [12]. Fauzia Siddiqui et al. (2017) explained the design and analysis of a paper shredding machine with emphasis on its structural framework, transmission system, and cutting elements for effective working [13].
Ganesh U. L. et al. (2017) designed a shredder for coconut and areca leaves with the goal of converting agricultural waste to manure and minimizing waste accumulation [14]. Garrett C. Fitzgerald et al. (2009) outlined the way that pre-shredding municipal solid waste may enhance heat transfer and combustion efficiency within waste-to-energy processes [15]. How-Ji Chen et al. (2017) applied the Takochi optimization method to find the best conditions for the manufacture of lightweight aggregates from tile sludge and sediment [16]. Ignatius Pulung Nurprasetio et al. (2017) emphasized the ecological load created by disposable plastic containers in institutions and communities, citing that single-use plastic restrictions are increasingly being made necessary [17]. Ishwar Sarvade et al. (2018) dwelt on developing a plastic bottle recycling machine, thus facilitating efficient waste minimization and sustainable plastic waste management [18]. Jeffrey Weiss et al. (2009) made shredding equipment adaptable to fit the production ability and cost limit of the developing world such as Haiti, making it more accessible and usable [19]. Juraj Beniak et al. (2012) reported a lack of research on optimizing shredding machines, particularly in terms of energy efficiency and material savings [20].
Jibrin Sule et al. (2017) touched on the common usage of concrete and suggested the use of recycled materials like plastic in order to minimize environmental pressures [21]. Jaypalsinh Ran et al. (2020) highlighted the development of agricultural practices, which are essential for the survival of human beings and play an important role in the solution of food shortages via sustainable agriculture [22]. Kathleen Vinck et al. (2019) presented a forensic method for reconstructing torn documents, underlining its significance in criminal investigations and document restoration [23]. Khilesh Sarwe et al. (2014) proved that plastic waste, if treated well, can be utilized in concrete, providing an answer to the increasing challenge of plastic waste build-up [24]. L. Recchia and M. Daou (2018) discussed the necessity for shredder machines for small-scale farming, proving that locally manufactured machines can provide for this at affordable costs [25]. Lhakpa Wangmo Thingh Tamang et al. (2017) stated that the excessive cost of plastic waste recycling machinery forces users to depend on packaging and external treatment, rendering the whole process costly economically [26]. M. Muthukumaran et al. (2017) redesigned shredders to accommodate the lifestyle and process needs of local users with a focus on improving recycling efficiency through customized refinement [27]. M. F. Nasr et al. (2019) wrote about the extensive usage of plastics in packaging and the intricacies in plastic waste management because of its non-homogeneous composition [28].
Norshah Aizat Shuaib et al. (2016) noted improvements made in predictive modeling in energy consumption, improving the reliability and accuracy of forecasting energy and waste [29]. Rianti Dewis Sulamet Ariobimon et al. (2016) demonstrated the sensitivity of aluminum compared to steel regarding the width of the specimen during tensile testing to unravel the material behavior under different dimensions [30]. Moussa M. Lebloubar et al. (2016) cautioned against the toxic emissions resulting from unsafe disposal of waste, naming it as the leading cause of environmental and health hazards [31]. Mr. S. B. Zote et al. (2016) suggested minimizing the generation of dross and salt cake in recycling aluminum and creating useful applications for these byproducts [32]. P. O. Awoyeraa et al. (2020) addressed the yearly production of organic waste in restaurants in Belgium and suggested methods to recycle it economically [33]. Sekar Ravi et al. (2018) stressed the need to educate communities about the use of plastic shredders, making them understand that one can efficiently and effectively dispose of waste when equipped with proper machinery [34]. Sekar L. R. et al. (2016) reaffirmed that plastic shredders play a significant role in creating awareness and efficiency in the disposal of waste at a local level [35]. S. Nithyananth et al. (2014) discussed traditional agricultural waste disposal methods, urging more environmentally friendly measures [36]. Shyam Thapa et al. (2020) highlighted the energy potential of lignocellulosic farm biomass and its contribution towards renewable energy development [37]. Saima Hamid et al. (2020) advocated a circular system where waste is considered a resource, bridging the waste generation and utilization gap [38].
Tamás Bányai et al. (2019) discussed trends in urban waste generation fueled by high population growth and demanded upgraded systems for recycling and collection in a timely fashion [39]. Vladimir Vasek et al. (2005) examined the advantages of fiber-reinforced cementitious composites, observing their constructional durability and mechanical strength [40]. Ying Liu et al. (2016) recognized the necessity for new recycling methods for polymer composites, particularly in material reuse-limiting industries [41]. Yong Wang et al. (2018) considered the vehicle routing optimization within two-echelon logistics networks, demonstrating how transport can be optimized [42]. Zhou Xianyan et al. (2016) observed that recycling end-of-life vehicles helps to lower environmental pollution, although improved shredder design and failure analysis are still needed [43].

3. Layout and Design Set Up

3.1 Layout & Design of the Set-up

Set up consists of shredder assembly for crushing waste material using 2 hp electric motor. Procedure for experimentation is in the way that firstly Start electric motor then Put the gathered waste one by one (aluminum, plastic, wood, rubber). Ensure effective crushing by converting it into minute particles. Repeat the procedure for every waste material. Collect all crushed material into separate bags [18].

Fig 2: Schematic layout of shredder machine

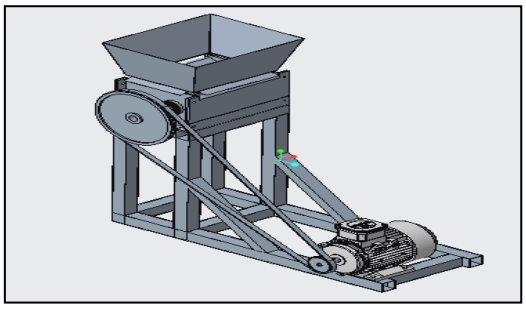

Fig 3: SM solid modelling

3.2 Lab Testing

Firstly Mix the coarse aggregate in each crushed material to form sample. Mixing proportion of each material with cement, water and other chemical binder material is given below. After mixing pour the material in cube of 150 mm × 150mm × 150mm. Keep this admixture with 8 to 10 hours for fine binding. After that remove the fine aggregate from cube and test it lab. (Costrologix). Final results into finding compressive strength of composite of each aluminum, plastic, wood, rubber and mixture of all material in equal proportion.[1]

4. Summary

As Per objectives design development and analysis of shredder machine component is done as well as the optimization of shredder component and byproduct composites from wastages is also optimized. It has been observed that in optimization of shredder components the mild steel is the material is very useful for fabrication. This material is cost effective and having less stress and deformation in all categories. General purpose of the shredder is to crush the waste materials like plastic, rubber, wood, aluminum to form composites from them. Generally problem regarding with shredder machine is that vibration is more, due to which there may be failure of parts in the operation. So in order to reduce this we must find the beast optimal solution by finding best suitable material. [6] [29] Also bi-products from waste concrete aggregate also optimized to find the best optimal solution form all material. In this survey aluminum material is optimized because this material is having less stress, deformation and higher compressive strength among all materials. Also aluminum is available in the industry in raw form. But as compared to aluminum we need to gather the other materials like plastic, wood, rubber form an environment. All mixture materials also having higher strength but only problems associated with that when the aluminum material get finished then we need to gather it again to mix it in all mixture [10] [19].

5. Result & Discussion

1. Design and development of all innovative component of shredder machine is done, design done on the basis of actual stress and allowable stresses induced in the component in the form of von-misses stress. Also by finding the deformation induced in parts to resist against the failure.[33]
2. All the manufactured parts are assembled to make prototype. Different type of fabrication procedure is used to assemble all parts of shredder machine.[20]
3. According to design and development I construct a shredder machine which will shred 1 kg of plastic, wood, glass, Aluminum to convert heavy material into small particle after crushing. The capacity of shredder depends upon the size of the hopper. Hopper design in the way that it take one kg of plastic at time , because out of all four material only the plastic is the heavy material in size.
4. Test of innovative machines by means of crushed produced from wastages to recycle it is done. It is effectively ensure that the output of crushed part is in the form of smallest part not in the form of heavy part.[21]
5. Cutter is deigned in the way that it is validated in the ansys to make ensure the forces acting on that could not damages its point. So that cutter design is the main component design to make ensure better efficiency of project.[14]
6. Optimization solution is applied in the report to find the better solution. Optimization is done in at the stage of manufacturing and at the result stage. In the stage of manufacturing the optimization of material stress is done. Generally material having lesser equivalent von- misses stress and lesser deformation is optimized. Also in testing stage material optimized in the way that finding the better material form all four material to ensure best crushing strength of the material. The Aluminum material is optimized.[12]
7. The results obtained in the form of crushing strength or compressive strength of the material. As the compressive strength of the material is greater than it can withstand. Those material having higher compressive strength, they can withstand deformation and strain.[24]

Out of total survey the aluminum material having higher compressive strength is observed. In research there are several parameters on which the total project depends, such as the total knowledge of the structure, the design of the single plate also its arrangement of the main shaft, reducing rotation. The study of motion in software was successfully carried out when the whole assembly is done. The frame needs basic analysis to check whether it could take desired load or not. The following analysis was done in ANSYS 20.0 and the results were positive. Before starting the actual fabrication, we conducted a trial on our prototype just to ensure the desired results with our design. The prototype testing was also positively conducted. [11] The actual fabrication was started over prototype testing but there was a problem with gear alignment and the bearing plate fitting. So we need to change our reduction gear position at the end due to the pulley arrangement. These difficulties were overcome by some technical advice. There was a problem of waste material jamming which was eliminated by the use of stripper's fingers. There are very less vibrations in the actual and settled condition of the machine. [10] After design and manufacturing the machine the operation is performed instantaneously. In this the designed machine has obtained the power with the use of electric supply from the utilized electric motor also electric motor has been provided with the electrical energy that was transported into mechanical energy by the gears of the machine, which can be employed to diminish the motor speed. The result is that the plastic shredder must reduce the speed of the electric motor to the desired speed and successfully cut the paper into the small strips. [23] It is worth noting that readily available materials cheap but high strength & durability were used in designing this project to reduce production costs of wastages. Hence, the designed plastic shredder machine prototype model can demonstrate the work satisfactorily and stated earlier which fulfilled the purpose

and objectives. Therefore such process has effectively utilized to cut plastics into incomprehensible waste in offices, houses and business sectors. [30]

5.1 Optimization of Composites Material

Table: 1 Tabulation for total deformation, equivalent (von-misses) stress, equivalent elastic strain & compressive strength of all composites.

Sr. No	Material	Deform-ation (mm)	Strain	Stress ($N/mm^{2)}$	Compressive Strength ((N/mm2) (Expt.)	Average Compressive Strength (N/mm2)(Expt)
1	Concrete + All Mixture	0.11062	0.0010627	31.881	28.7	28.5
2	Concrete + Alu-minum	0.11062	0.0010503	31.508	28.9	28.6
3	Concrete + Rub-ber	0.11047	0.0008925	26.775	25.9	27.1
4	Concrete + Plas-tic	0.11044	0.0008604	25.814	24.9	26.9
5	Concrete +Wood	0.1103	0.0007571	22.713	21.9	23.3

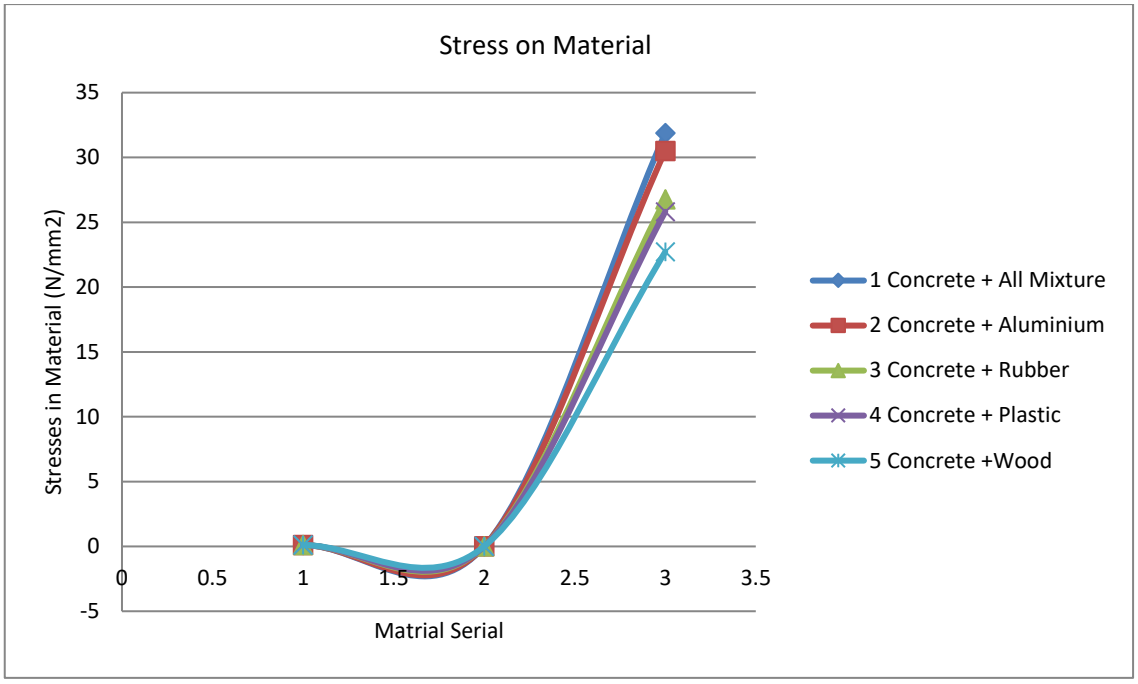

Fig 4: Graph for stress on different composite material

All the values tabulated in the tables clearly show that compressive strength is higher of all mixture material and somewhat for aluminum. So that stresses are lessens for the material.

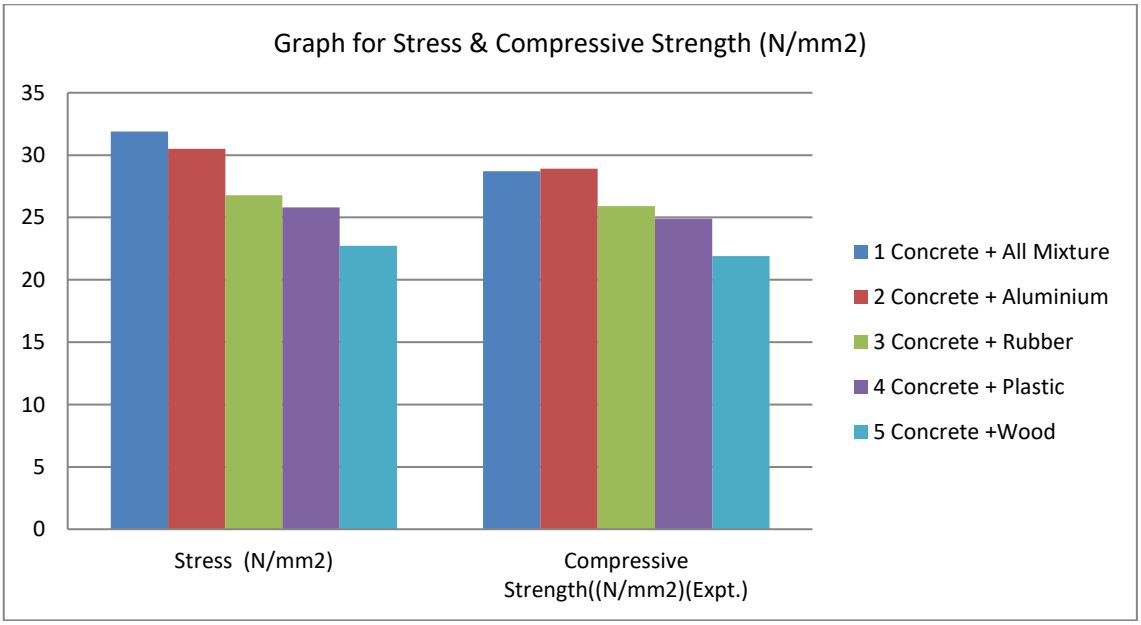

Fig 5: Graph for stress & compressive strength for different composite material

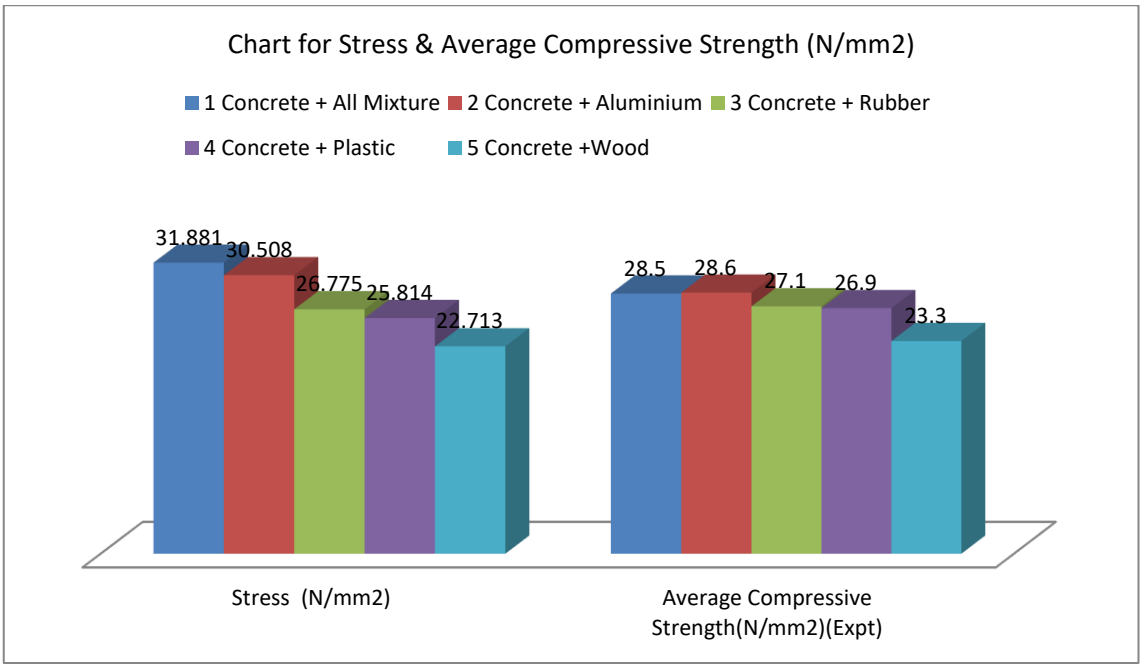

Fig 6: Chart for stress & average compressive strength for different composite material

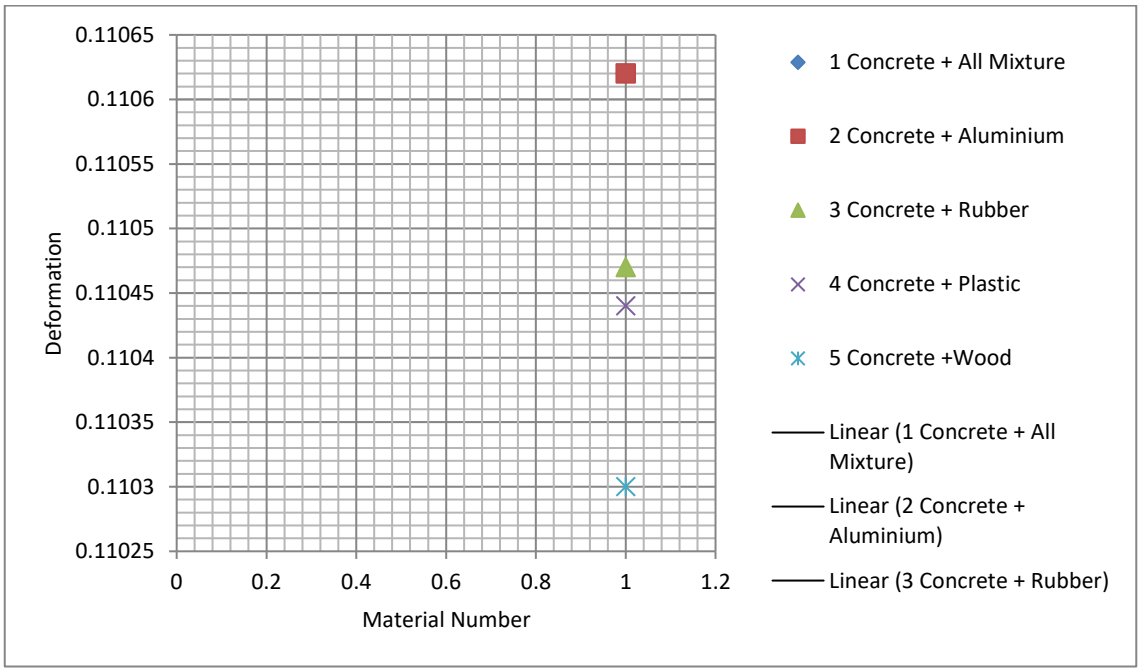

Fig 7: Graph for deformation of material

1. As the equivalent von-misses stress increases then compressive strength also increases (Negligible increase in the stress than the other material does not affect the strength of material).
2. Deformation and strain go on increasing with respect to increasing stress.
3. Material of aluminum and all mixture having higher compressive strength than other material.
4. Out of these four material all mixture & aluminum is optimized, in comparison these two, aluminum is optimized because this material having higher compressive strength to withstand load, also if we take example of wastages aluminum is easily available in the raw form from industry but it is not cheaply available as compared to plastic (we need to gather plastic from many places).

6. Conclusion

Out of total survey the aluminium material having higher compressive strength is observed. In research there are several parameters on which the total project depends, such as the total knowledge of the structure, the design of the single plate also its arrangement of the main shaft, reducing rotation. The study of motion in software was successfully carried out when the whole assembly is done. The frame needs basic analysis to check whether it could take desired load or not. Before starting the actual fabrication, we conducted a trial on our prototype just to ensure the desired results with our design. The prototype testing was also positively conducted. The actual fabrication was started over prototype testing but there was a problem with gear alignment and the bearing plate fitting. So we need to change our reduction gear position at the end due to the pulley arrangement. These difficulties were overcome by some technical person advice. There was a problem of waste material jamming which was eliminated by the use of stripper's fingers. There are very less vibrations in the actual and settled condition of the machine. After design and manufacturing the machine the operation is performed instantaneously. In this the designed

machine has obtained the power with the use of electric supply from the utilized electric motor also electric motor has been provided with the electrical energy that was transported into mechanical energy by the gears of the machine, which can be employed to diminish the motor speed. The result is that the plastic shredder must reduce the speed of the electric motor to the desired speed and successfully cut the paper into small strips. It is worth noting that readily available materials cheap but high strength & durability were used in designing this project to reduce production costs of wastages. Hence, the designed plastic shredder machine prototype model can demonstrate the work satisfactorily and stated earlier which fulfilled the purpose and objectives. Therefore such process has effectively utilized to cut plastics into incomprehensible waste in offices, houses and business sectors.

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