Iraqi Journal of Industrial Research (IJOIR)

Journal homepage: http://ijoir.gov.iq

Effect of Increasing Calcium Carbonate (as a Filler) on the Plastic Pipes Properties

Fatima Atiye Lafta, Suhir Abdel Aziz Jabber*, Thana'a Abdul Amir, Ali Nazim Abdul Kerim, Lehib Abdul Hussain

State Company for Construction Industries, Ministry of Industry and Minerals – Iraq

Article information

Article history:
Received: Month, xx, 2022
Accepted: Month, xx, 2022
Available online: October, 20, 2022

Keywords:
Calcium carbonate ($CaCO_3$),
Plastic pipes,
Unplasticized polyvinyl chloride

Corresponding Author:
Suhir Abdel Aziz Jabber
phy.sci.suhir@gmail.com

DOI:
https://doi.org/10.53523/ijoirVol9I2ID233

Abstract

Calcium carbonate ($CaCO_3$) was used as a filler in the mixture for plastic pipes to improve the mechanical properties of the product, this research dealt with the study of the effect of increasing the proportion of calcium carbonate ($CaCO_3$) on the properties of the produced pipe through a factory application by preparation of five mixture of polyvinyl chloride with different proportions of calcium carbonate (3, 5, 8, 10, and 15)% with some additional materials for the manufacture of the plastic pipes by using the extrusion method to produce polyvinyl chloride pipes (110mm × 10bar × 6m) for transportation of drinking water,a series of tests were carried out on the raw materials: (bulk density, free flow and sieve analysis) and also on the final product: (dimensions, heat reversion, tensile strength, impact strength, resistance to external blows and strength characteristics determined by long-term hydrostatic strength (rupture), the results of the tests showed a decrease in the tensile strength by increasing the percentage of calcium carbonate addition and by a small amount up to 8% and the decrease became more clear when the percentage of calcium carbonate addition was more than 8%, the results obtained at the level of factory application have proved the possibility of increasing the proportion of calcium carbonate in the mixture of raw materials used in the manufacture of unplasticized polyvinyl chloride (U.P.V.C) pipes (from 3 to 8 %) and the results of the tests on the final product conformed to the certified specification for the proportion of 3, 5, and 8% and did not conform to the certified specification for proportions 10 and 15%.

1. Introduction

The polymer is a word of Greek origin where “poly” is a synonym of” many”, while “meres” stands for “parts”. Plastic is a polymeric material with a large molecular weight and it is in a solid state when produced. It is called plastic due to its ability to form and mold when heated, it has been widely used due to its good physical and chemical properties. Polyvinyl chloride has many advantages as it is not electrically conductive, and it has a high resistance to corrosion, bases, acids, and alcohols[1, 2, 3].

Unplasticized polyvinyl chloride (U.P.V.C) is one of the most common and widely used polymers in the plastic industry and usually (in its natural state) it is not suitable for use from a mechanical point of view it is a solid material (breakable) and to improve its specifications. A set of additives are added to it and there are two types of these materials, rubber-like polymeric materials and very soft inorganic materials which represent the filler material such as calcium carbonate, which is found in nature and purest of it in the Sulaymaniyah governorate in Iraq and the north of Wadi Al-Abyad, about 30km southeast of the city of Ain Al-Tamr, east of Karbala cement factory and the models that were brought from the Wadi Al-Abyad region was adopted to conduct this research. The plastic pipe production process goes through the stages (grafting stage, cooling, and heating stage, extrusion stage, and cutting stage)[4]. Over the past decades, Polyvinyl chloride (PVC) has become one of the dominant construction materials in urban drainage systems, as well as for drinking water and gas distribution networks, is used in many industrial products, the most important of which is that it is used in the manufacture of plastic pipes and sewage pipes where they have a long service life and is used in packing electrical wires, as well as in medical devices, blood storage bags, window blinds, paint in automobile, building construction and packaging fields [5, 6, 7, 8, 9]. And calcium carbonate is used in many fields for example in the paint industry as an aid in rubber processing as an additive in the paper industry as well as in the medical purposes, in the manufacture of chemical fertilizers, pesticides and glass and as a filler in the plastic industry, calcium carbonate improves some of the physical properties of the plastic product they make an antioxidant where it raises its stability and resistance and make it a good external appearance as well as a texture in addition they make it easy to treat and raise its fluidity and scattering, the use of calcium carbonate in the plastics industry reduces production costs because it is much cheaper than petroleum and other raw materials and calcium carbonate constitutes (80%) of all fillers used in the plastic industry of which approximately 65% are consumed from (U.PV.C) compounds with an annual consumption rate of about 6 million tons, its wide use is mainly related to presence in abundance in nature and with good purity and this in turn is reflected in the low cost of processing as it is produced in different sizes and with multiple processes that include drying, grinding and softening to a granular size ranging from 100μ to less than 5μ [10]. Maruthi concluded that the proportion of 8% of calcium carbonate in the mixture of raw materials for the manufacture of plastic pipes gives the life of the pipe up to 50 years and a lower cost by reducing the percentage of polyvinyl chloride [11].

This research aims to study the effect of increased calcium carbonate proportion on the properties of the produced pipes by a laboratory application according to the specification.

2. Experimental Procedure

The research was carried out in two stages:

Stage1: physical and chemical tests were carried out for raw materials used in this research for calcium carbonate and polyvinyl chloride (Tables 1, 2, & 3), respectively. The purity of calcium carbonate was calculated depending on the molecular weights of calcium carbonate and calcium oxide and the percentages of oxide resulting from the dissolution of calcium carbonate during thermal treatment, as shown in (Table 1). Some tests have been carried out on polyvinyl chloride (Volumetric density, Compressed volumetric density by vibration, Free flow, Sieve analysis), shown in (Table 3).

Stage2: an application was carried out on a laboratory level for the production of (U.P.V.C) plastic pipes for the transportation of drinking water with proportions of 3, 5, 8, 10, and 15% of calcium carbonate all laboratory conditions the were adopted, and the laboratory tests were carried out for the final product(dimensions, heat reversion, tensile strength, impact strength, resistance to external blows and strength characteristics determined by long-term hydrostatic strength(rupture)) according to the German specifications DIN 8061[12], DIN 8062 [13], ISO 6259 [14] (Table 4).

3. Results and Discussion

The results shown in Table (4) and Figure (1) for impact strength testing indicated that the percentage of broken specimens (10%) conformed to the specification limits when calcium carbonate addition was 3, 5, and 8%, while the percentage of broken specimens increased to 50 and 70% when calcium carbonate addition was 10 and 15% it did not conform to the specification and the reason is due to the heterogeneity of the polyvinyl chloride with the increasing proportion of calcium carbonate which led to such cracks, shown in Figure (2).

The results of the tensile strength shown in Table (4) and Figure (3) indicate that the tensile strength decreases with the increase in the addition of calcium carbonate, and it decreased by a little and it was 500, 505, and 515kg/cm^2 when calcium carbonate addition was 3, 5, and 8%, respectively while decrease became more noticeable and it was 140 and 170kg/cm^2 when calcium carbonate addition was 10 and 15%, respectively, the reason is due to the heterogeneity of the polyvinyl chloride with the increasing proportion of calcium carbonate, shown in Figure (4).

The results shown in Table (4) and Figure (5) for resistance to external blows testing indicated that the percentage of broken specimens (10%) conformed to the specification limits when calcium carbonate addition was 3, 5, and 8% while the percentage of broken specimens increased to 60 and 40% when calcium carbonate addition was 10 and 15% it did not conform to the specification and the reason is due to the heterogeneity of the polyvinyl chloride with the increasing proportion of calcium carbonate which led to such cracks as shown in Figure (6).

The results obtained in the Table (4) and Figure (7) indicate that the time to failure decreased with the increase in the percentage of calcium carbonate addition, and the time to failure at 3, 5, and 8% was 60 min bearing the applied pressure resulting from the equation for this testing, and it was within the limits of the specification, while the time to failure decreased by 15 and 20 min and the time was outside the specification limits when calcium carbonate addition was 10 and 15%, respectively as shown in Figure (8). The additions of calcium carbonate by more than 8% affected the mechanical and physical properties of the pipes and the reason is due to the heterogeneity of polyvinyl chloride with high calcium carbonate addition, which led to the pipes breaking and not conforming to the specification requirements.

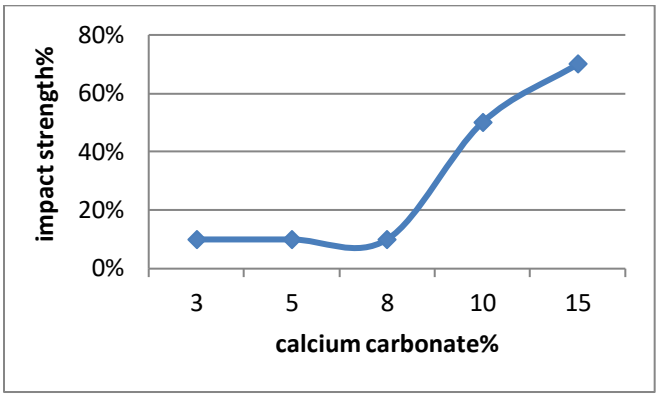

Figure (1). Relation between impact strength and the percentage of addition of calcium carbonate.

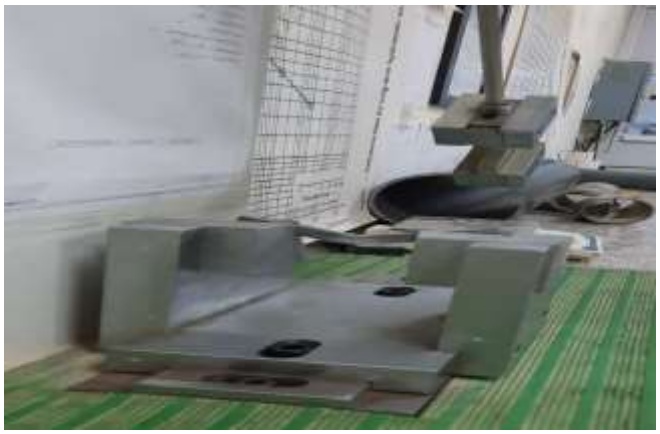

Figure (2). Cracking of PVC after impact strength test.

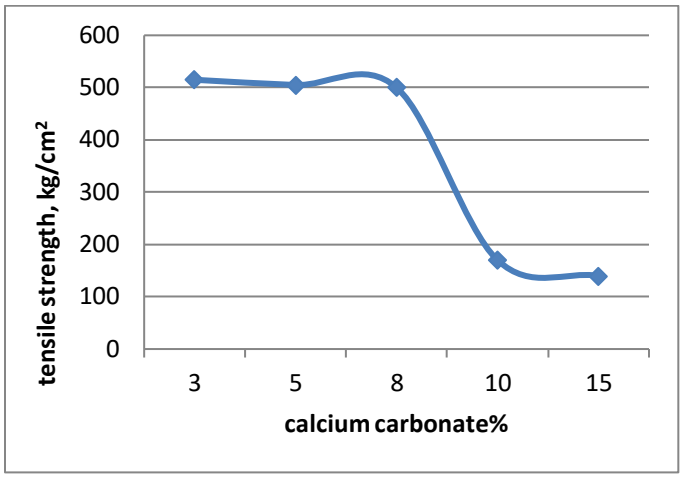

Figure (3). Relation between tensile strength and the percentage of addition of calcium carbonate.

Figure (4). Cracking of PVC after tensile strength test.

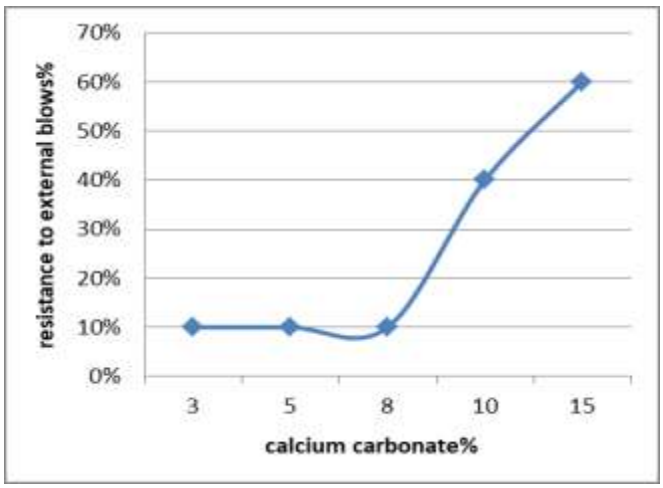

Figure (5). Relation between resistance to external blows and the percentage of calcium carbonate.

Iraqi Journal of Industrial Research, Vol. 9, No. 2 (2022)

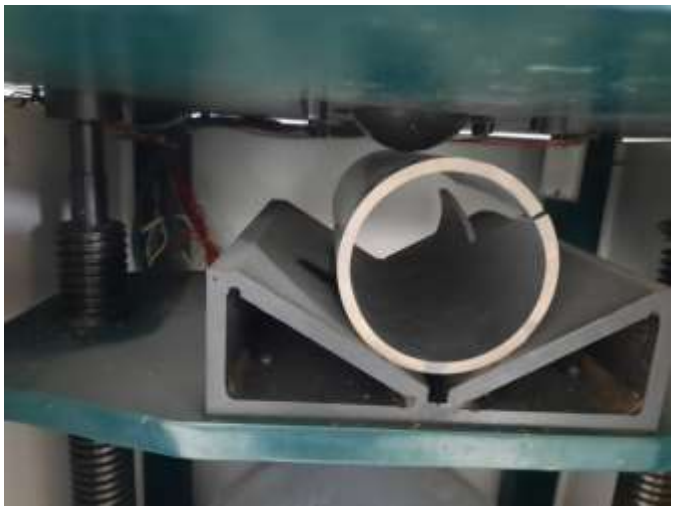

Figure (6). Cracking of PVC after resistance to external blows test.

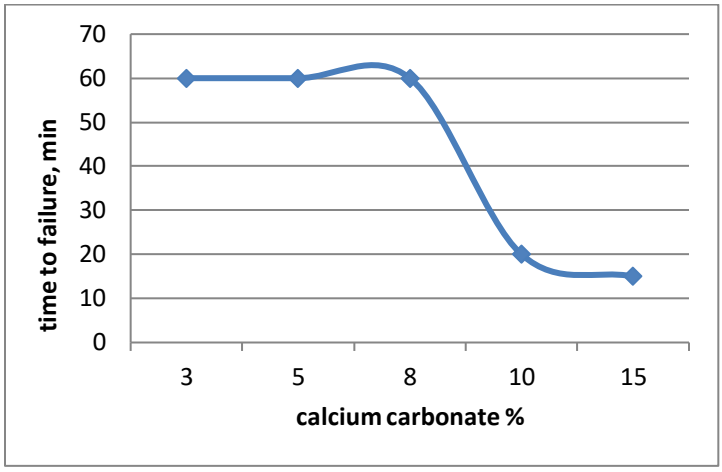

Figure (7). Relation between time to failure and the percentage of addition of calcium carbonate.

Figure (8). Cracking of PVC after rupture test.

Table (1). Results of chemical analysis for calcium carbonate.

s.	sample	SiO_2 (%)	Al_2O_3 (%)	CaO (%)	FeO_3 (%)	MgO (%)	Loss (%)	purity percentage (%)
1	Calcium carbonate	0.2	0.68	54.04	0.24	0.74	42.3	$CaCO_3$
2	factory specification	0.12≈	0.25≈	54.85≈	0.13≈	0.18≈	42.9≈	96.4

Table (2). The results of the physical tests of calcium carbonate.

s.	sample	insoluble in HCl (%)	pH	specific weight	density(g/cm^3)
1	Calcium carbonate	0.8	8.44	2.7	0.89
2	factory specification	1	-	2.6-2.7	0.89

Table (3). The results of the physical tests of Polyvinyl chloride.

s.	Test name	Measuring unit	actual	Specification limits
1	Volumetric density	g/l	562	(550-600) g/l
2	Compressed volumetric density by vibration	g/l	pass	Depends on the size and shape of the particles
3	Free flow	-	pass	the powder coming down from the first three funnels (that is up to (4 mm) diameter)
4	Sieve analysis	%	87.7%	(87%) on a sieve with a diameter of (125 µ)

Table (4). Test results of PVC pipes with different percentages of calcium carbonate (6m × 10bar × 110mm).

Surface quality	$CaCO_3$%	Specification limits (DIN8062:2009)[13]						Actual results					
		Thickness mm	Diameter mm	Impact strength	tensile strength Kg/cm^2	resistance to external blows	Rupture Kg/cm^2	Thickness mm	Diameter mm	Impact strength	Tensile strength Kg/cm^2	Resistance to external blows	Rupture Kg/cm^2
Straight pipes, the inner and outer surface of the pipe are free from extrusion	3	5.3-6.1	110-110.4	Broken pieces not more than 10%	500-600	Broken pieces not more than 10%	The sample shall with stand the internal pressure calculated from the equation based on thickness and diameter for an hour (60min)	5.5	110.2	10	515	10	With stand 44 pressure for (1hr)
	5							5.3	110.3	10	505	10	With stand 42.4 pressure for (1hr)
	8							5.3	110	10	500	10	With stand 42.5 pressure for (1hr)
	10							5.4	110.2	50	170	40	Exploded at 43.3 after (20min)
	15							5.6	110.2	70	140	60	Exploded at 44.9 after (15min)

4. Conclusions

It can be concluded from the above that the proportions of calcium carbonate at 3, 5, and 8% can be used in the production of plastic pipes. The results of the tests conducted on the final product conformed to the certified specifications. Calcium carbonate (8%) was used in the raw material mixture for the production of plastic pipes, Which is considered the best percentage in terms of reducing production costs and with test results within the approved specifications, which guarantee the life of the pipe to up to 50 years.

References

[1] B. A. A. Majeed and D. A. sabar, "Effect of Kaolinite on the Mechanical Properties, Thermal Properties, Flammability, and Water Absorption Percentage of Poly (Vinyl Chloride) Composite.", *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 18, no. 2, pp. 27 – 39, 2017.

[2] M. Mohammadzadeh, "Characterization of Recycled Thermoplastic Polymers," Master Thesis, School of Engineering, University of Boras, Boras, alsuwayd, 2009.

[3] M. Muhammad and A.S. Salih." Study the effect of temperature on structural, mechanical and thermal properties of PVC/ CaCO3 composite. ", *Iraqi Journal of Science*, vol. 59, no. 1, pp. 44-56, 2018.

[4] W. S. Bryant and H. E.Wiebking. "The Effect of Calcium Carbonate Size and Loading Level on the Impact Performance of Rigid PVC Compounds Containing Varying Amounts of Acrylic Impact Modifier.", ANTEC 2002 Annual Technical Conference, vol. 3, pp. 1-5, 2001.

[5] K. F. Markis, J. G. Langeveld, and F. H. L. R. Clemens, "Extensive Testing on PVC sewer pipes towards identifying the factors that affect their operational lifetime.", *Structure and Infrastructure Engineering*, pp.1-13, 2021.

[6] A. O. Dawood, "Structural Performance of PVC Large-Diameter Gravity Sewer Pipes Installed in Maysan Province According to Iraqi Procedure", *International Journal of Civil Engineering and Technology (IJCIET)*, vol. 9, pp. 1201–1214, 2018.
[7] N. J. Hammed and H. W. Qasim, "Study of Weathering Effect on the Thermal Conductivity of Poly (Vinyl Chloride) Before and After Silicon Carbide Addition as Packaging Materials", *Iraqi Journal of Physics*, vol. 14, no. 29, pp. 82-89, 2016.
[8] K . Endo, "Synthesis and Structure of Poly (Vinyl Chloride)", *Journal Progress in Polymer Science*, vol. 27, no.10, pp. 2021-2054, 2002.
[9] A. Muhson, I. Y. Mohammed, and S. A. Al-bayaty. "Mechanical and Thermal Degradation Kinetic Study of Basalt Filled Polyvinyl Chloride Composite Material." *Egyptian Journal of Chemistry*, vol. 64, pp. 893-901, 2021.
[10] H. Wiebking, "Fillers in PVC a Review of the Basics ." *Specialty Minerals Inc*, 1998.
[11] M. P. Yadav, H.Raghavendra, G. L. Rao, et al., "An Experimental Analysis on the Effect of Filler Material (CaCO3) on PVC pipes.", *International Journal of Engineering Research and Reviews*, vol.3, pp. 48-55, 2015.
[12] DIN 8061, Unplasticized polyvinyl chloride (PVC-U) pipes, 2009.
[13] DIN 8062, Unplasticized polyvinyl chloride (PVC-U) pipes, 2009.
[14] ISO 6259-2, "Thermoplastics pipes-Determination of tensile properties", 1997.