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RESEARCH PAPER

Performance of Grape Extract Addition as an Admixture in Concrete Construction

Mahmood, H.F.[1*], **Dabbagh, H.**[2] **and Mohammed, A.A.**[3]

[1] Associate Professor, Civil Engineering Department, University of Halabja, Kurdistan Region, Iraq.
[2] Assistant Professor, Civil Engineering Department, University of Kurdistan, Sanandaj, Iran.
[3] Professor, Civil Engineering Department, College of Engineering, University of Sulaimani, Kurdistan Region, Iraq.

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ABSTRACT: Chemical admixtures are widely used for the production of high-performance concrete, but they are responsible for environmental pollution and health issue during construction because of their chemical nature. Also manufactured admixtures are expensive, on this base recently, researches and attempts are focused to find alternatives, and using different natural or bio admixtures for concrete is a good choice. In this study, the impact of Grape Extract (GE), a natural additive, on the properties of concrete was investigated. Various GE percentages were used to investigate the properties of fresh and hardened concrete. The results show that there is a continuous workability enhancement and continuous splitting tensile strength loss with GE increase. Improvement of 28 days compressive strength by 18.5% was observed on using 0.22% GE, while no compressive and flexural strengths loss was observed with GE addition up to 0.55%. Finally, the results of the study showed that GE dosages can strongly impact the fresh properties and mechanical strength of concrete mixtures. So there is a chance to produce self-compacting concrete using GE natural admixture instead of chemical admixture but there is a need for further experimental tests.

Keywords: Compressive Strength, Flexural Strength, Grape Extract, Slump, Water Absorption.

1. Introduction

A chemical admixture is a material besides water, aggregates, or blended cement that is used as an additive in concrete or mortar and is added to the batch directly before or during mixing. Admixtures are substances added to concrete mixes to alter or enhance the properties of fresh and/or hardened concrete, according to the ASTM C-494 standard. Typically, the admixture is added in small amounts ranging from 0.005% to 2% by weight of cement (Li, 2011). Although it is advantageous to use chemical admixtures consciously to improve the early and final properties of cementation materials, Chemical admixtures also allow for the production and construction of

* Corresponding author E-mail: e.hershfaqe@gmail.com

specialty concretes such as high fluidity concrete, high strength concrete, underwater concrete, and sprayed concrete (Plank et al., 2015).

Chemical admixtures also contribute to environmental pollution. When they are in concrete, and are released into the atmosphere, many of them are Insafe for human consumption (Faqe et al., 2020). Chemical admixtures also have leaching issues in hardened concrete where it comes into contact with drinking water, as well as in normal structures where leaching could affect the environment in which it is placed, and corrosion due to chemical content is a major problem affecting the durability, strength, and sustainability of buildings and structures (Tangtakabi et al., 2022).

Nowadays, concrete construction techniques are directed toward eco-efficiency, a technology that aims to manufacture highly durable and environmentally friendly concrete while minimizing both environmental load and production costs. (Kim and Chae, 2017). Trying to discover alternative admixtures is highly beneficial in the construction of environmentally friendly concretes.

According to historical records, ancient structures left by Egyptians, Greeks, Romans, and Indian civilizations were usually built with lime as a binding medium, and this material was a versatile material to use in traditional temples and monuments (Thirumalini and Sekar, 2013). Additionally, different bio admixtures were used by the builders to prepare their lime stuccos. The actual aim of using such admixtures is not truly recognized (ACI Education Bulletin E4-12, 2013). However, the builders were certain that using plants and animal derived as natural admixtures in lime mortar can improve the durability and strength of the mortar.

In modern concrete construction, many types of admixtures have been used to provide a more cost-effective method and enhance the properties of the concrete (Patel and Deo, 2016). Different studies have already worked on natural material as alternative for chemical admixture, which are commonly used in concrete construction. Although organic or natural admixtures may have been a viable option abundant; their production is not technologically advanced, and creates green construction (Mahmood et al., 2022).

Researchers have shown various cases with the development of bio-based admixtures that perform as well as oil-based polymers used as admixtures. The researchers drove that they have improved concrete's mechanical properties, durability, and sustainability. Based on reviewing the published works on using natural admixtures in concrete, Table 1 was prepared, from which test variables attempted and the action of admixture have been illustrated. According to the study's results, the necessity of using admixture in concrete, and the problems with using chemical admixture, which is harmful to human health and causes leaching, which is responsible for environmental pollution, natural admixture as an alternative to chemical admixture is the best way for making sustainable concrete. The main purpose behind this study is to investigate the performance of normal strength concrete containing grape extract natural admixture. The grape tree (see Figure 1), which belongs to Vitis, Species Vinifera of the family Vitaceae, has been grown and dispersed worldwide for over 2000 years. The chemical composition and nutritional condition of grape trees can be influenced by a variety of climatic, topographical, and soil conditions (Mansour et al., 2022). The fruit is generally eaten fresh or dried, and it is also used to manufacture wine, fruit juice, jam, and canned food. In the Kurdistan region, grape juice has a relatively low cost because the tree is widely planted, and on this foundation, there is an increased possibility that grape extract might be used as a natural admixture in the production of concrete in place of chemical admixtures. However, because of lack of information on this topic, there is a need for experimental laboratory works to highlight different properties of modified concrete with this natural admixture. Unfortunately, in the author's idea there is not any research on the action of grape extract added on the hardened, and fresh properties of concrete to illustrate the action of the grape extract addition. The subject of this investigation could not be related to some studies' attempts to use natural solid waste in concrete, due to the fact that grape extract cannot be considered as waste material. The grape extract from the grape tree's fruit was used in the current investigation with the dosage of (0, 0.22%, 0.33%, 0.44%, 0.55%, and 0.66%) by cement weight, in order to assess the applicability for concrete production. Properties of fresh and hardened concrete to be examined in this study are workability using slump test, water absorption and using a scanning electron microscope device to analyze morphology. In addition, some tests on hardened concrete including compressive strength, splitting tensile strength, modulus of elasticity and modulus of rupture have been performed. Based on the results of such a laboratory work, this additive can be used in actual applications to enhance the performance of concrete production. Considering that the resource of this admixture is natural, and the production of the concrete is environmentally friendly, it can be classified as a low-cost, environmentally friendly construction material with a promising future in the construction industry.

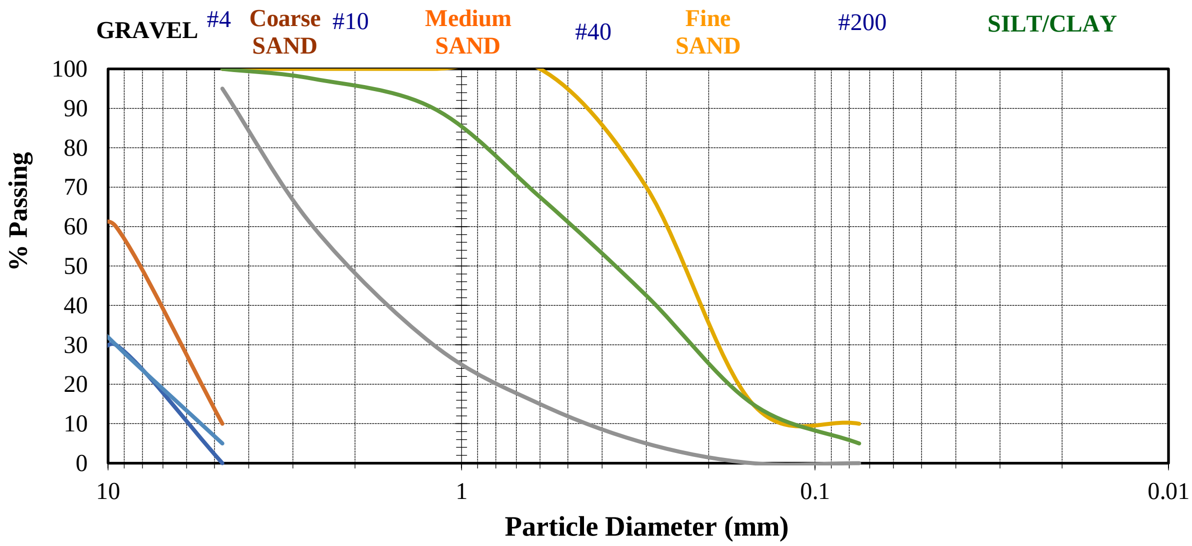

Fig. 1. Sieve analysis aggregates graph (course and fine)

Table 1. Description of test variables attempted by the past researches

Reference	Type of NA	Addition	Property studied	Action of NA in concrete
Chandra and Aavik (983)	Black gram	1,3,5% (Cement weight)	Air content, water absorption, compressive strength.	Black gram worked as air-entraining admixture, water absorption is reduced, while compressive strength is increased.
Chandra et al. (1998)	Cactus extract	50,100% (Water replacement)	Density, water absorption, compressive strength, freezing-thawing resistance.	Density and water absorption are decreased, compressive strength is reduced at early ages, and freezing-thawing resistance is increased.
Ismail et al. (2009)	Natural rubber latex (NRL)	1.5,3,5% and 2.5,5,7.5,10%	Sodium sulphate resistance (SSR), water absorption.	1.5% NRL is the optimum dosage for SSR, 5% NRL resulted in low absorption.
Otoko and Ephraim (2014)	Palm liquor (PL)	5,15,25,35% (Water replacement)	Setting time, slump, compressive strength, splitting tensile strength.	Slump, compressive strength AND tensile strength were increased up to 15% PL then decreased, initial and final setting times are increased with increasing PL.

Woldemariam et al. (2014)	Cypress tree (CT)	5,10,15% (by weight of water)	Consistency, setting time, flow table, compressive strength	Initial and final setting times increased, workability increased (OD=5%), compressive strength is increased (OD = 15%). Performance of boiled extract is better than the soaked extract.
Sathya et al. (2014)	Water hyacinth (WH)	10,15,20% (Water replacement)	Setting time, slump, compressive strength, water absorption.	Setting time, slump and compressive strength were increased (OD = 20%). Water absorption is reduced.
Woldemariam et al. (2015)	Blue gum (BG)	5,10,15% (by weight of water)	Shrinkage, cracking.	Shrinkage is reduced, OD is between 10% and 15%. Using BG will reduce shrinkage cracking even the concrete is subjected to direct heat from the sun.
Otunyo and Koate (2015)	Sugar cane juice (SCJ)	3,5,10,15% (Water replacement)	Slump, setting time, compressive strength.	Setting times were delayed. Slump was decreased. Compressive strength was reduced up to 10% SCJ.
Patel and Deo 2016)	Gram flour	1% (Cement weight)	Electrical resistivity, UPV, carbonation depth.	Electrical resistivity was increased, UPV is nearly not changed, and carbonation depth is reduced.
Muhammed et al. (2016)	Pulp black (PB)	1,1.5,2%	Slump, flow, compressive strength, splitting tensile strength.	Slump, flow value, compressive strength, splitting tensile strength are increased up to 1.5% PB then decreased.
Amaran and Ravi (2016)	Cactus (OFI)	10,20% (Water replacement)	Standard consistency, setting time, workability, compressive strength.	Standard consistency, initial and final setting times, workability, compressive strength are increased with increasing cactus up to 20%.
Paul et al. (2017)	Natural rubber latex	0.5,0.8,0.9,1,1.5% (by cement weight)	Compacting factor, compressive strength.	There was a compacting factor decrease with latex content of minimum loss at 0.9%. There was a compressive strength enhancement up to 0.9% latex followed by a strength loss.
Amrita et al. (2017)	Aqueous extract of okra	(1:10, 1:20, 1:30, 1:40, 1:50) gm(okra): liter(water)	The consistency, water retention capacity, compressive strength, and water absorption capacity and porosity with durability properties	Improved water retention capacity of cement pastes, and viscosity enhancing, also improves mechanical and durability performances of cement mortar and concrete.
Ramesh and Neeraja (2017)	Hen egg	0.25,0.5,0.75, 1,1.5% (Binders weight)	Normal consistency, setting time, slump, compressive strength.	Normal consistency is increased (OD=1%), setting time is reduced, compressive strength, tensile strength and elastic modulus are increased (OD =0 .25%), slump is reduced (OD = 0.75%).
Ramesh et al. (2017)	Hen egg	0.25,0.5,1% (Concrete volume)	Water absorption, porosity, acid attack.	Water absorption and porosity are reduced; acid attack resistance is increased (OD = 0.25%).
Pathan and Singh (2017)	Molasses	0.4,0.6,0.8% (by cement weight)	Slump, setting time, compressive strength, splitting tensile strength, flexural strength.	There is a slump increase, setting time increase, slight increase of compressive, slitting tensile, flexural strengths are increased with increasing molasses up to 0.8%.
Elinwa et al. (2018)	Gum Arabic (GA)	0.25,0.5,0.75, 1% (by cement weight)	Workability, density, water absorption, compressive strength.	Slump, porosity and water absorption are increased with GA increase, Optimum dosage is 0.5% for compressive strength enhancement.
Andayani et al. (2018)	Copolymer - natural latex methacrylate (KOLAM) and copolymer	1,5,10% (by cement weight)	Compressive strength, Dynamic properties: load and energy dissipation.	There is a compressive strength reduction except for mix with 1% KOLAM. Impact load is reduced and energy dissipation is increased on using 1% KOLAM. KOLAS addition into concrete mixture does not give good performance in strength and impact properties.

	- natural latex styrene (KOLAS)			
Aquilina et al., (2018)	Cactus (OFI)	10,20,40,60% (Water replacement)	Consistency, setting time, compressive strength, UPV.	Flow is decreased, setting time is increased, compressive strength and UPV are reduced at early ages.
Azizi et al. (2019)	Opuntia ficus-indica Cladodes	1, 2.5 and 4% of Opuntia ficus-indica cladode's powder by weight of cement	Setting time and compressive strength.	Setting times were reduced significantly with the addition of Opuntia ficus-indica cladodes, and mechanical strength and resistance to acetic and hydrochloric 5% acid solution were enhanced over the control sample.
Mechaymech and Assaad (2019)	Cellulose-based VEA, modified-startch VEA	0.02,0.035,0.05and 0.08% VEA	Slump flow and J-Ring tests.	The rheological properties with VEA additions given the higher degree, The mixes prepared with cellulose VEA showed the maximum levels of stability, including deformability and resistance to bleeding and surface settlement, at a VEA dosage of 0.035%.
Torres-Acosta and González-Calderón (2021)	Opuntia ficus-indica (OFI) cactus	0%, 1.5%, 4%, 8%, 42%, and 95%, by water mass replacement Concentration.	Electrochemical Characterization. linear polarization resistance (LPR) measurements.	Because corrosion rates and cracking initiation/propagation were decreased, it was useful as a corrosion inhibitor for steel in carbonated cement-based materials.
Abana et al. (2021)	Pulverized Water Hyacinth	0.5%, and 1% of pulverized water hyacinth by weight	Setting time and strength.	Comparing a concrete cylinder containing 0.5% and 1% pulverized water hyacinth to that without, they show an improvement in compressive strength of 2.39 and 3.83%, respectively.
Paul et al. (2022)	Sugarcane Juice (SCJ)	0, 2, 5, 10, 20% (Water replacement)	Initial and final setting time, workability, compressive strength, and splitting tensile strength of concrete.	The setting time was reduced with the increased SCJ content in the mix. As an accelerator, The compressive strength of concrete increased as the SCJ content increased in the concrete mix.
Mahmood et al. (2023)	mulberry extract	0,0.22,0.33,0.44,0.55 and 0.66% of cement content	Slump test, water absorption and morphology analysis, compressive strength, splitting tensile strength, modulus of elasticity and modulus of rupture	Increase in the slump of concrete with increasing mulberry liquid up to 0.66%, and accordingly dosage of 0.33% (optimum dosage) of the mulberry extract caused a reduction in water absorption and an increase in compressive strength.

NA = natural admixture, OD = optimum dosage.

2. Materials

The concrete mixtures contain cement, fine aggregate, coarse aggregate, water and liquid grape extract. Ordinary Portland cement (Type I ASTM) was used in all concrete mixes. Which are manufactured by the Tasluja factory in Sulaimani and characterized as ordinary Portland cement-II/A-L 42.5 R. The chemical and physical properties of cement are presented in Table 2. It can be proved that the cement meets the requirements with the Iraqi specification's limits. As a coarse aggregate, particles of crushed aggregate with a maximum size of 19 mm and fine aggregate, natural river sand with a fineness modulus of 1.87 were used. The results of the sieve analysis test on the aggregates are shown in Figure 1 and Table 3. Both aggregates were checked to satisfy with the (BS 812, 1990) limitations. Clean potable water was used for mixing concrete and curing specimens. The natural admixture employed in this study was grape liquid, which was made from the fruit of a grape tree native to Iraq's Kurdistan region (see Figure 2). The density of the liquid was determined to be 1.335 g/ml. Table 4 shows the chemical composition and mineral concentrations. The liquid was then investigated with EDX and XRD images as shown in Figures 3 and 4, respectively. Figure 5 shows the microstructure view of the dried grape juice using an SEM device.

Table 2. Properties of OPC and limits of Iraqi specification

Chemical properties	**Results**	**Limit of I.Q.S No. 5/1984**
Lime saturation factor, %	0.94	0.66 - 1.02
Magnesium oxide (MgO), %	3.58	Not more than 5%
Sulfate content (SO_3), %	2.28	Not more than 2.85%
Loss on ignition (LOI), %	3.48	Not more than 4%
Insoluble substance, %	0.78	Not more than 1.5%
Physical properties	**Results**	**Limit of I.Q.S No.5/1984**
Finesse (Blaine), m^2/Kg	345	Not less than 230 m^2/kg
Initial setting time, minute	175	Not less than 45 min.
Final setting time, hours	3:35	Not more than 10 hrs.
Soundness (expansion), %	0.22	Not more than 0.8%
Compressive strength (3 days), MN/m^2	35.6	Not less than 15 MN/m^2
Compressive strength (7 days), MN/m^2	47.3	Not less than 23 MN/m^2

Table 3. Sieve analysis of coarse and fine aggregates

Coarse aggregate			**Fine aggregate**		
Sieve size (mm)	**% passing**	**BS 882 limits**	**Sieve size (mm)**	**% passing**	**BS 882 limits**
37.5	100	100	4.75	100	95-100
19	70	90-100	2.63	97.5	60-100
12.5	42	-	1.18	90	30-100
9.5	30	30-60	0.6	67.5	15-100
4.75	5	0-10	0.3	42.5	5-70
			0.15	15	0-15

Table 4. Chemical composition and minerals content of grape liquid

Chemical composition		**Mineral contents**	
Dry Matter (%)	58.84	Al (ppm)	41.39
Moisture (%)	41.16	Ca (ppm)	589.68
Ash (%)	0.64	Fe (ppm)	58.57
Protein (%)	2.28	K (ppm)	3714.29
Fat (%)	0.12	P (ppm)	478.19
Fiber (%)	0.2	Rb (ppm)	2.94
Carbohydrate (%)	55.6	Zn (ppm)	3.17
Phosphorous (%)	0.04	Mg (ppm)	457.14
Calcium (%)	1	Na (ppm)	69.21

(a) (b) (c)

Fig. 2. View of grape: a) tree; b) fruit; and c) extract

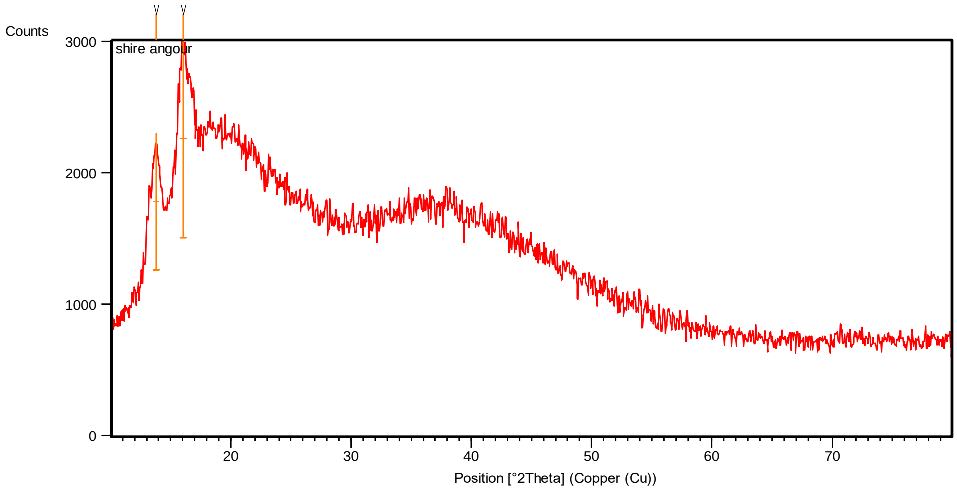

Fig. 3. EDX picture of grape extract

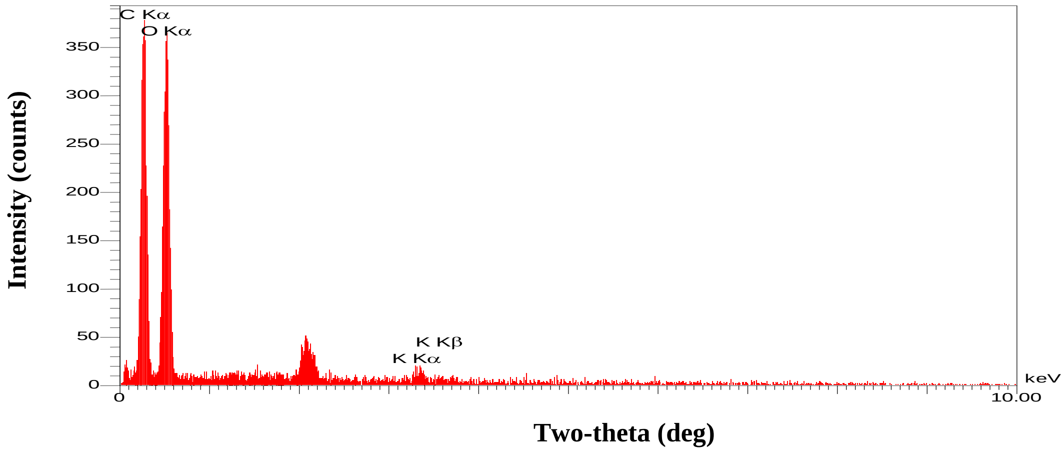

Fig. 4. XRD of grape extract

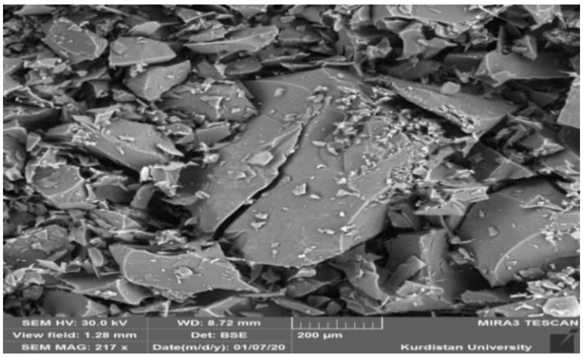

Fig. 5. SEM view of grape extract powder

3. Mix Design and Procedure

Based on the previous experience, the control concrete mixture (without any grape liquid) was chosen, and the target compressive strength was set at 35 MPa. Table 5 illustrates the proportion of the mix design, with the water/cement ratio of 0.55, and the amount of grape extract (GE) as the major variable investigated. This admixture was added to the concrete mix at a dosage of 0.22 %, 0.33 %, 0.44 %, 0.55 %, and 0.66 % by the cement weight.

For mixing concrete, an electrical tilting drum was used. Cement and other dry components were first added to the mixer and left to rotate for two minutes. After adding some mixing water, the mixture was left for another minute to combine. The remaining water containing the liquid grape extract was then added, and the concrete mixture and left to mix for three minutes until it was homogeneous. All internal parts of steel molds were carefully lubricated before concrete casting to facilitate in the remolding of hardened concrete. The concrete specimens were compacted by external vibration (see Figure 6a). After 24 hours, the specimens were taken out of the mold and placed in a water tank to cure for 3, 7, 28, and 90 days at a temperature of roughly 25 °C. Three days before testing, the samples were taken out of the water tank and dried at the lab.

4. Instrumentation and Testing

Fresh concrete was determined by slump test, which using a standard slump cone, as recommended by (ASTM C143, 2013). At the ages of 28 and 90 days, hardened concrete cube specimens of (150 × 150 × 150) mm were used for water absorption tests. Compressive strength was determined on 150 × 300 mm cylinder specimens using the Turkey model testing machine (Figure 6b), in accordance with the (ASTM C39 specification, 2013). Splitting tensile tests on 150 × 300 mm cylinders were done in accordance with (ASTM C496 specifications, 2013), whereas the flexural strength testing was done on 100 × 100 × 400 mm concrete prisms in accordance with (ASTM C78 specification, 2013). In addition, according to ASTM C469 (2013) 150 × 300 mm cylinders were used to measure modulus of elasticity. For the tests listed above, an average of three values were obtained, and results were reported. Additionally, using an FEI QUANTA 400 model scanning electron microscopy apparatus, a morphological analysis of small portions of hardened concrete was done after compressive strength testing.

5. Results and Discussion

The results of testing specimens for different concrete properties are shown in Table 5. The sections that follow are given to a lengthy discussion of the results.

Table 5. Experimental test results

Mix code	Slump (mm)	Water absorption (%)		Compressive strength (MPa)				Splitting tensile strength (MPa)		Flexural strength (MPa)	Elastic modulus (MPa)
		28 days	90 days	3 days	7 days	28 days	90 days	28 days	90 days	28 days	28 days
MC	43	4.37	4.01	19.81	23.13	32.53	34.75	2.09	2.53	5.5	23654
MG0.22	57	4.01	3.72	24.44	33.80	38.54	40.64	2.01	2.34	5.99	25313
MG0.33	68	4.21	3.80	26.53	31.98	35.33	36.04	2.0	2.28	5.99	20594
MG0.44	83	4.33	3.89	20.58	29.66	33.23	35.36	1.99	2.19	5.55	20569
MG0.55	97	4.41	4.00	14.97	22.67	31.89	34.65	1.78	2.12	5.41	20973
MG0.66	123	4.46	4.14	1.63	4.25	25.28	25.11	1.56	1.45	5.35	21360

(a) (b) (c)

Fig. 6. Photos of: a) Specimens subjected to vibration; b) Compressive strength machine; and c) Cast specimens

5.1. Workability

Slump test results for various dosage of GE content are shown in Figure 7. When the percentage of Grape Extract (GE) in the concrete mix is increased, the slump gradually increases, from the beginning. The control mixture was made with a relatively small slump value of 43 mm. It was expected that the addition of GE can improve workability, due to the sugar content. Slump value increases with increased liquid addition, reaching 123 mm (286%) at the dosage of 0.66% GE, showing a more than twice increase in workability. The simplest group of carbohydrates, which is made of carbon, hydrogen, and oxygen is the source of the slump development in the extract liquid. As shown in Table 4, the GE used in this study includes approximately 55.6% carbohydrates (or sugar). Sugar in mixing water enhances workability (the optimal amount is 16%), according to Otoko and Ephraim (2010). Also according to Pathan and Singh (2017), adding molasses, a byproduct of sugar, improves workability by up to 0.8% of cement weight. Based on the findings, there is a possibility of using a lower water/cement ratio in the concrete mix when GE is added for a constant slump as compared to control concrete. It will produce in a concrete with a higher compressive strength. However, additional testing is required to assess this performance experimentally because the high sugar content makes concrete volume expansion and does not set as shown in Figure 10.

5.2. Water Absorption

The results of the water absorption test at 28 and 90 days are shown in Figure 8. Water absorption decreases with increased grape liquid at 28 and 90 days, reaching 8.2% and 7.2% when 0.22% GE is used, respectively. As a result, 0.22% is considered the optimum dosage of the GE additive in regards to water absorption. The factors governing hardened concrete absorption capacity generally are the same as those that modify concrete compressive strength, and the positive effects of GE addition can be compared to changes that the GE addition causes in the microstructure and pore structure of hardened cement paste. The following section provides more detail about this.

5.3. Compressive Strength

Figure 9 indicates the change in compressive strength with the addition of grape liquid for concrete tested at different ages.

The compressive strength of concrete tested at 3 days is increased by 34% when 0.33% of the GE additive is used. Maximum strength improvement relates to 0.22% GE addition, which is equal to 14.6%, 18.5%, and 16.9% at ages (7, 28, and 90) days, respectively. It should be noted that the 3 days compressive strength with 0.33% GE is higher than the 7 days control mix and that there is a continuous loss of compressive strength with increasing grape liquid content, with the maximum compressive loss of 92% occurring at the age of 3 days with the dosage of 0.66%. It should be highlighted that this may be because ages, segmentations, and filling of capillary pores are partially fulfilled by the hydration product primarily represented by the C-S-H gel, and so there is no need for significant GE addition. According to the results, a higher GE is more influence on the compressive strength of the concrete at the age of 3 days This low strength can be attributed to the fact that the existence of GE in concrete in a large amount has a vital effect against the cement hydration development. Figure 10 shows one cylinder made of concrete with 0.66% GE tested at 3 days, from which one can observe a complete distortion of concrete indicating a very low strength. The results also show that the high strength loss reduces with increasing concrete age, primarily due to cement paste hydration development, and that some of the strength loss is restored when compared to the concrete tested at 3 days. The previous discussion will lead to decide that 0.22% GE is the optimum dosage to be added to concrete, and there is a degradation of strength with increasing the extract addition. The potential and actual reasons for an increase in compressive strength as a result of GE's addition to concrete is discussed in details as follows. Three major factors can be attributed to the GE addition's improvement of pore structure, reduction of absorption, and gradual development. It is important to know that GE extract has the following components: Organic acids, nitrogenous compounds, sugars, phenolic chemicals, chemical compounds, minerals, and pectic substances. The first reason for the enhanced microstructure and strength is due to the liquid's amount of sugar. The extract consists of 94.5% carbohydrates, based on Table 4. According to Ashworth (1965) studies, adding sugar to concrete enhances compressive strength by around 8%. Deva et al. (2017) showed that using 0.06% sugar in concrete mixes at different water/cement ratios improves the strength. Second, the influence of mineral components plays a role in the increase in strength. Potassium is the most common mineral in the liquid, accounting for around 50% to 70% of the cations. Table 4 shows that the potassium amount of the GE extract is 69%. The potassium absorbed by the fruit during ripening changes to potassium bitartrate (or potassium hydrogen tartrate) (C4H5O6), which reduces acidity and increases the pH of the juice. As a result, the GE ingredient is chemically compatible with the cement paste's hydration product. Crystals of potassium bitartrate may form within the pore structure of hardened cement paste. In addition to crystallizing during the fermentation of grape juice in containers like wine barrels and precipitating out of wine in bottles, potassium bitartrate is commonly known to be poorly soluble in water. With the development of cement paste hydration, there is a possibility that a sufficient amount of potassium mineral will crystallize inside the capillary poses within the cement paste mass, especially at early ages (3 days in this study), segmenting such pores, increasing homogeneity, and thus increasing compressive strength. The microstructure of concrete with and without the admixture, as shown by the results of the scanning electron microscope images in Figures 11a and 11b, varies. One may see an enlarged view of GE crystal precipitation completely blocking micro cracks. When Figures 11e and 11f, as well as Figures 11h and 11i, are compared, this situation appears as well. Another reason for the increased strength linked to the presence of GE in concrete is that GE contains phenolic chemicals, which are composed of two components: Anthocyanins and tannins, Tannins polymerize and age, which causes an increase in molecule size. On this basis, tannins may have the ability to fill in micro-cracks caused by cement hydration. Figure 11i may show the process of polymerization in which the produced chains tend to fill the existed crack gap. The results of Figure 9 also show that with a relatively large GE content (0.55%), 28 and 90 days compressive strength is quite similar to that of control concrete, knowing that on using such ratio there is about 126% increase in the slump of fresh concrete. As a result, there is an excellent chance that this natural additive will be used in the construction of self-compacting concrete. However, more experimental work is required to verify this. When 0.66% GE is used, there is a compressive strength loss, which can be attributed to the admixture's extremely strong thickening effect, which leads to a weaker material structure. Izaguirre et al. (2010) observed this impact while using potato starch in lime-aggregate mortar, or the strength loss may be attributed to the high sugar content related to the use of high GE content. Ahmad et al. (2020) showed compressive strength decreases when 0.2% sugar was used in concrete.

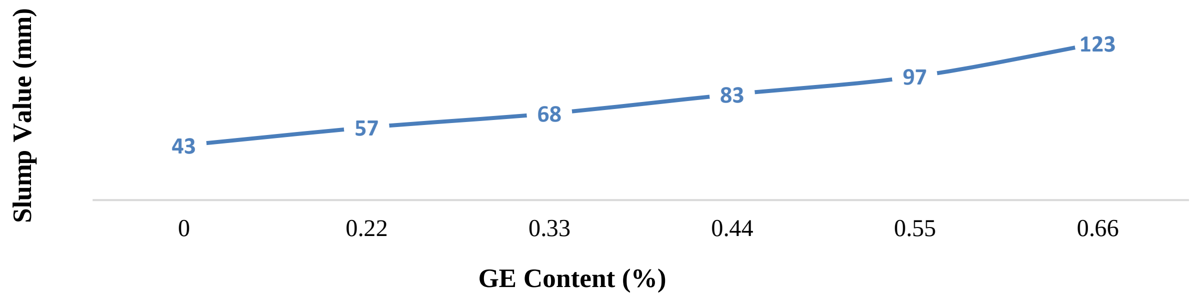

Fig. 7. Slump value with different ratio of grape content

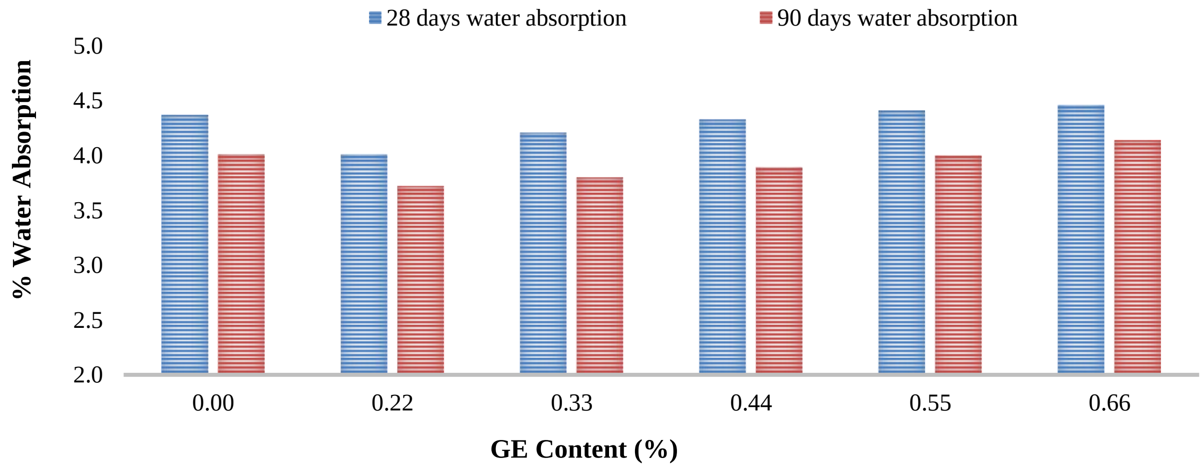

Fig. 8. Water absorption variation with GE contents

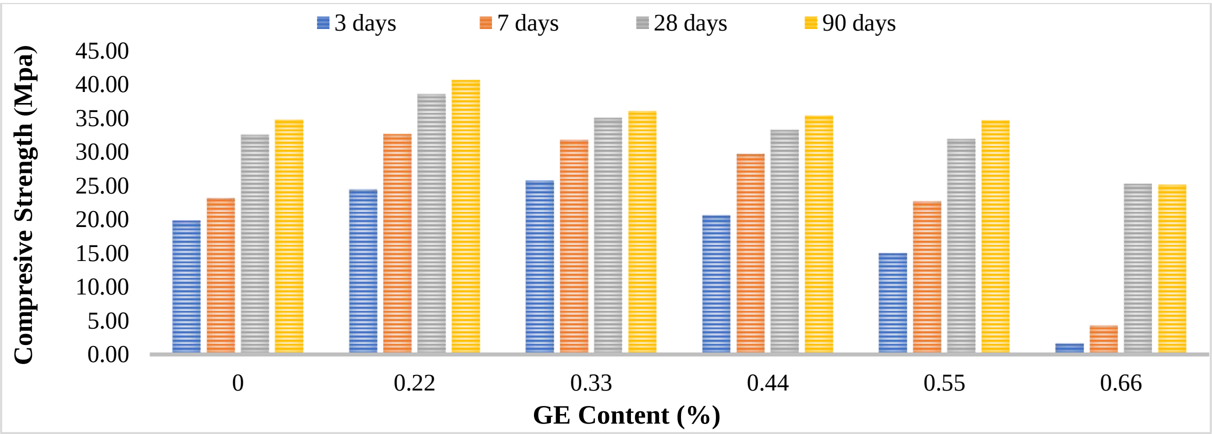

Fig. 9. Compressive strength variation with GE content

Fig. 10. View of a cylinder tested in compression (GE = 0.66%)

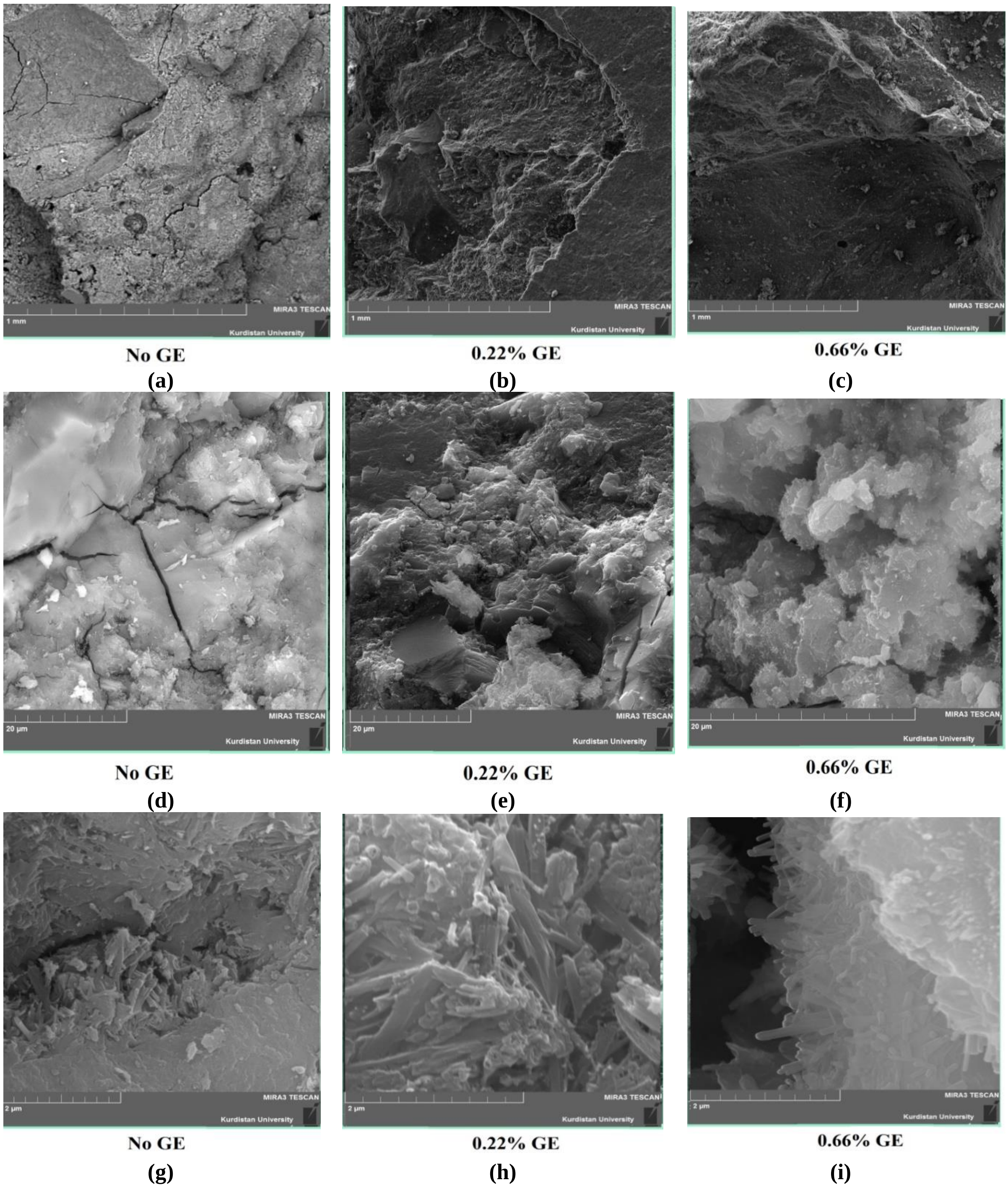

Fig. 11. Microstructure of concrete obtained by SEM analysis (28 days age)

5.4. Splitting Tensile Strength

Figure 12 shows the variation of the splitting tensile strength percentage with grape extract percentage. A constant decline of splitting tensile strength can be seen, reaching 25.4% and 42.9% at ages 28 and 90 days, respectively. Due on this, there is no optimum GE dosage for improving tensile strength as compared to compressive strength. At the age of 90 days, there is a 16.2% reduction in tensile strength when the liquid is used at an optimum dosage (0.22% based on compressive strength). In the practical applications of concrete based on using the GE natural admixture, this tensile strength loss as a result of GE addition to concrete should be taken into consideration. Totally, grape liquid has no beneficial effect to increase splitting tensile strength compared to the case of compressive strength. The relationship between the splitting tensile strength and compressive strength of concrete mixes analyzed at 28 and 90 days is presented in Figure 13. Because there is no statistically significant improvement in splitting tensile strength with the improvement in compressive strength, the correlation is not strong. The equations that were basically proposed for normal concrete to calculate splitting tensile strength based on compressive strength cannot be applied on this approach.

5.5. Flexural Strength

Figure 14 shows the change of flexural strength with GE ratio, indicating a strength development at all grape juice ratios except 0.55% and 0.66%. The maximum flexural strength obtained with 0.22% and 0.33% admixture is 9%, while the strength reduction with 0.66% GE is only 2.7%. In general, the behavior of concrete in flexure is similar to that in compression, but lower flexural strength enhancement is observed for the optimum dosage of grape liquid, and on using 0.66% GE, there is a lower flexural strength loss. Figure 15 shows flexural strength- compressive strength relationship, from which one can find that the correlation is similar to that of splitting tensile strength-compressive strength. Also, it will be observed that the equation given by ACI 318 Code (2015) is conservative for all ratios of GE admixture of average test/calculated value equal to 1.59.

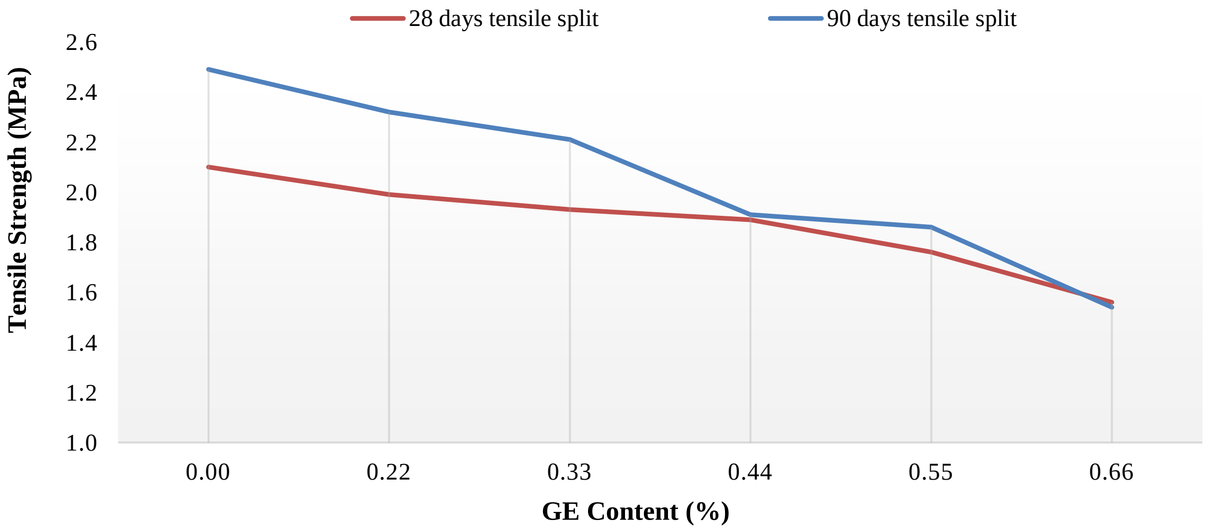

Fig. 12. Splitting tensile strength variation with GE content

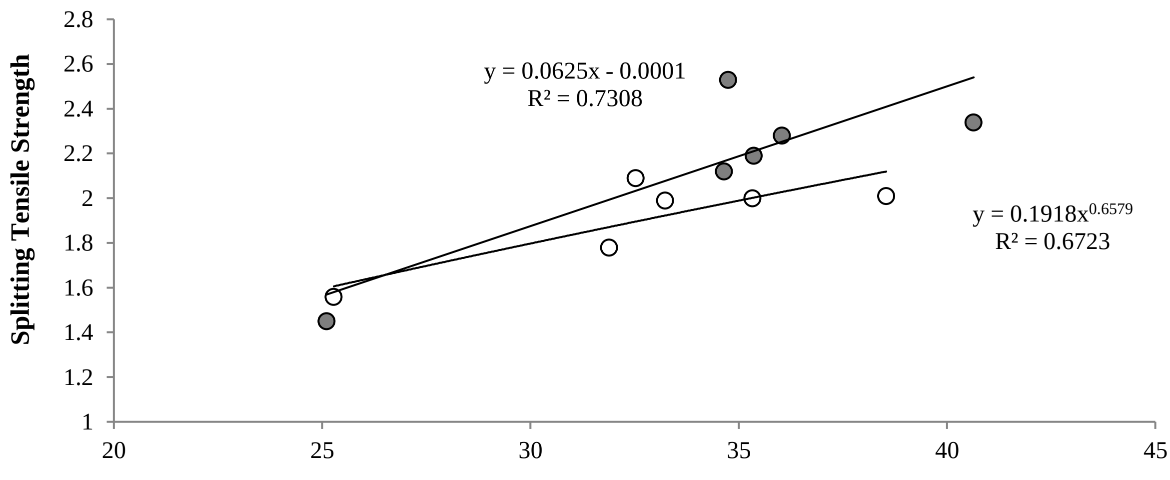

Fig. 13. Splitting tensile strength- compressive strength relationship

5.6. Modulus of Elasticity

The modulus of elasticity as a result of the concrete sample with different percentages of GE is shown in Figure 16. With the addition of GE, the elastic modulus increases slightly reaching its maximum value of 7% at a GE dosage of 0.22%. However, when the admixture increases to 0.66%, some elastic modulus is lost. The results line up with the observed compressive strength, therefore the optimum dose for enhancement is 0.22%, and at 28 days of age, 0.55% GE causes very little loss. The relationship between elastic modulus and compressive strength has weak correlation, as shown in Figure 17. Furthermore, it has been proven that the ACI 318 Code (2015) equation, which averages test/calculated values of 0.82, greatly overestimates test data when calculating the elastic modulus of concrete with GE admixture.

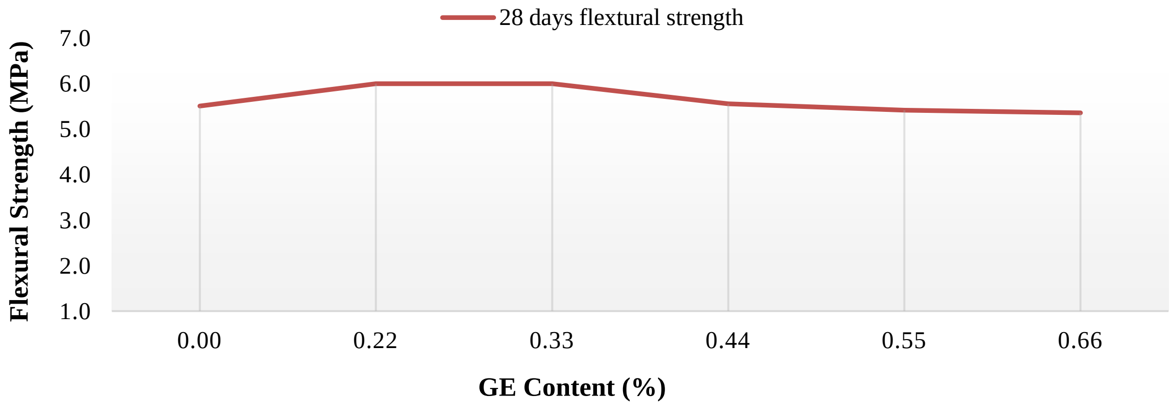

Fig. 14. Flexural strength variation with GE content

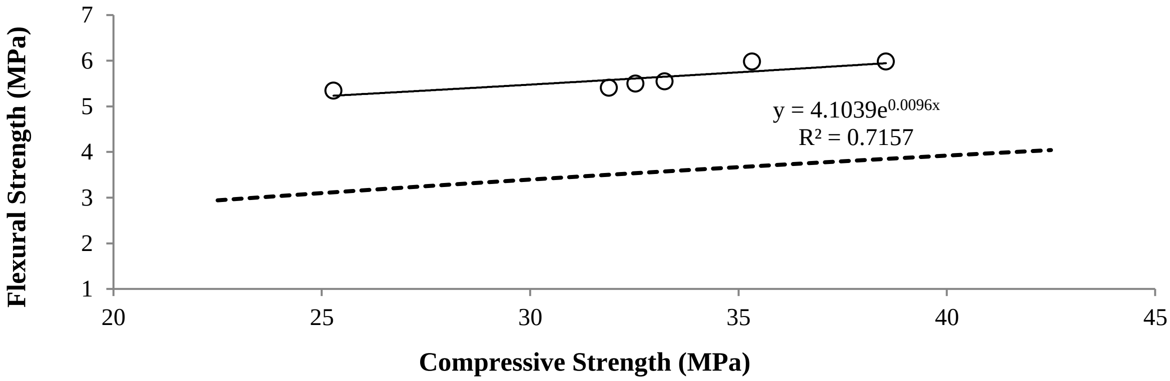

Fig. 15. Flexural strength- compressive strength relationship

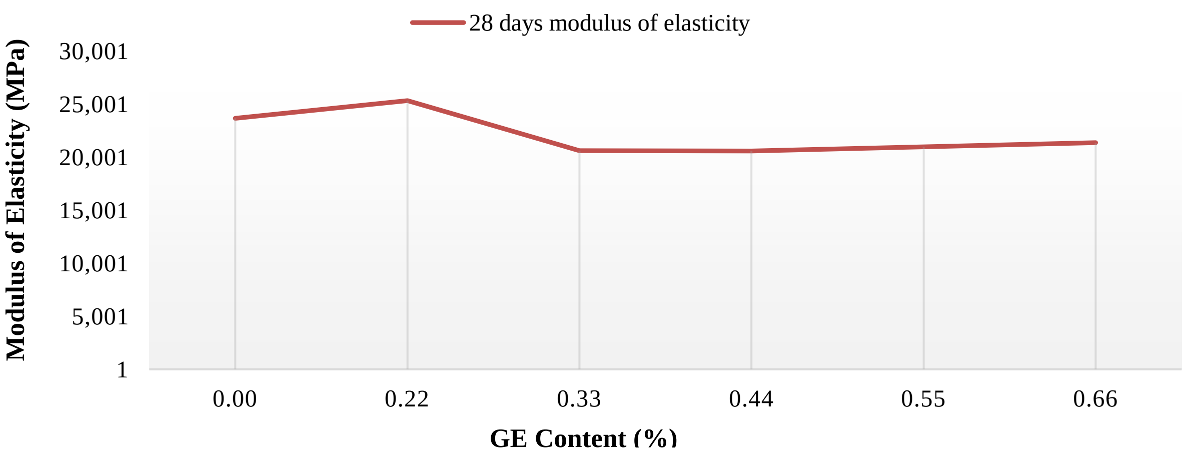

Fig. 16. Elastic modulus variation with GE content

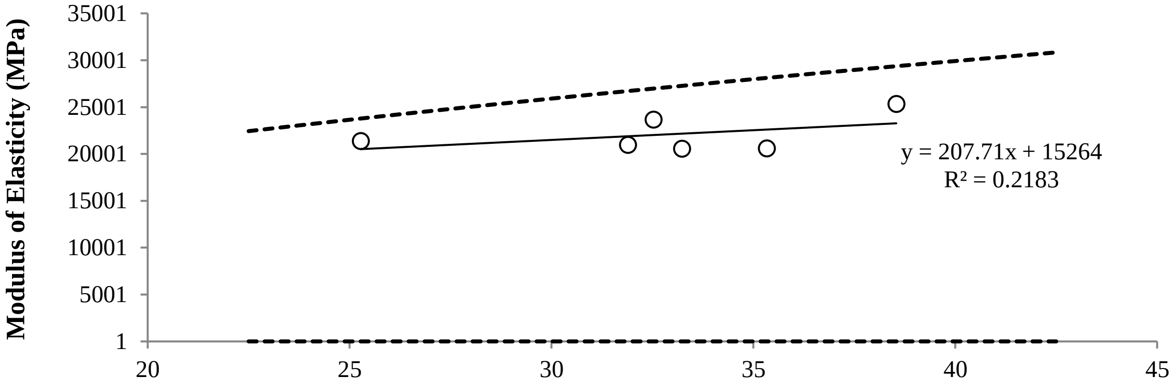

Fig. 17. Modulus of elasticity- compressive strength relationship

When 0.55% GE is used as a natural admixture, it will be noted that, there is a negligible water absorption loss, compressive and flexural strengths loss, while there is 16.2% splitting tensile strength loss and 11.33% elastic modulus loss as compared with the control concrete without GE. Fortunately, there is flow enhancement represented by the slump value equal to 126%, therefore one can conclude that there is a good chance to manufacture green self-compacting concrete using GE natural admixture added to concrete by 0.55% instead on using chemical admixtures.

6. Conclusions

The results of this experimental investigation into the properties of fresh and hardened normal strength concrete using grape extract as a natural admixture led to the following conclusions.

- Increasing the Grape Extract (GE) up to 0.66% produces a continuous increase in the slump of concrete, and as a conclusion, this natural admixture is working as flowing agent admixture. Using up to 0.55% GE in concrete resulted in no loss of compressive or flexural strength, but a 16.2% loss of splitting tensile strength and an 11.33% loss of elastic modulus. On this basis, there is a good chance that GE could be used instead of chemical additive in the construction of green self-compacting concrete.
- Using 0.33% GE, water absorption was reduced while compressive strength increased at age of 3-days, and the compressive strength was observed to be greater than control concrete of the age 7-days. When 0.22% GE is used in concrete, the 28-days compressive strength increases by 18.5%, and GE could be utilized to produce high-strength concrete when properly designed. The increased strength is mostly due to an improvement in the microstructure of the cement paste (seen from SEM test results), which is attributable to calcium precipitation in the porous structure of the cement paste.
- As additional GE is added to concrete, flexural strength follows the same trend as compressive strength, but with a less valuable strength increase, a slight elastic modulus loss, and a continual splitting tensile strength decrease.
- This study suggests engineers to use GE rather than chemical admixture because natural grape extract does not need advanced technology to produce, and the amount of optimum dosages is very small (0.22%) compared to chemical admixture 10-20%. So it is cost-effective, and the product will be more environmentally sustainable when using natural admixture.

7. Future Work

The properties of concrete products are improved by the use of GE as an admixture in the production of concrete. For evaluation and observation, more studies must be done on all types of concrete used in the construction of concrete structures. The effects of this additive on the properties of concrete that contained this admixture need to be studied further, and tests such as fire resistance and durability improvement, etc. were not implemented for this study.

Based on the outcomes of this study, it has been found that the effects of GE liquid on the properties of normal concrete can be used, especially for self-compacting concrete, due to the good workability results obtained in this study.

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