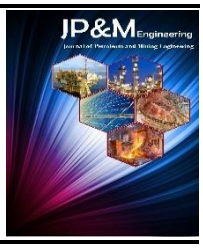
JP&M Engineering
Journal of Petroleum and Mining Engineering



# Novel Application of Dry Vinasse to Impove Properites of Concrete

Ahmed, A. M.[1], Omar A, F.[1], Mohamed M. A.[1], Mohamed A. A.[2] and Mahmoud, A.E.[3]

[1]Civil Engineering Eng Dept. Faculty of Engineering, Assuit University, Assuit, Egypt.

[2]Armant Sugar Factory, Egyptian Sugar & Integrated Industries Company, Luxor, Egypt.

[3]Mining and metallurgical Eng Dept. Faculty of Engineering, Assuit University, Assuit, Egypt.

*Corresponding author: atef66@aun.edu.eg, Tel. 0201091112751

**Article Info**

Received 12 Oct. 2020
Revised 03 Nov. 2020
Accepted 18 Nov. 2020

**Keywords**

Dry Vinasse; Compressive Strength; Durability; Concrete

## Abstract

The sugar industry in Egypt dates to the beginning at the nineteenth century. The sugar industry waste in Egypt has been used for recycling and used in the fields such as agriculture and industry. Also, some waste has recently been used in the construction fields. In this research, we had been studied the effect of using dry vinasse which is one of the sugar industry waste as additive material to improve hardened concrete properties and concrete durability, by studying the addition of various proportions of dry vinasse between 0.2 to 0.5% of the cement weight of dry vinasse, on cement mixtures 300, 350, 400 Kg/m$^3$ and then pouring concrete into standard cubes (15x15x15cm), beams (10x10x50cm) and cylinders (15x30cm) and curing then by submerging it in water until hardened concrete tests are performed every 28, 90, and 180 days. The durability test was done after 180 days. The cubes are cured in water for 28 days and then immersed in a solution contains 10% sodium sulfate until 180 days (included curing time). The results showed a noticeable improvement in both the compressive strength, flexural and splitting strength of concrete. Likewise, the resistances of concrete to deterioration are improved, after immersing the concrete cubes in sodium sulfate solution. The most favourable dose of dry vinasse found to be 0.4% dose.

## Introduction

Dry vinasse is a waste from the sugar industry, collected by drying the liquid vinasse which produced from the fermentation of molasses to produce ethyl alcohol. Vinasse causes many environmental problems as a result of getting rid of it, whether in rivers or deserts.

Several applications were conducted to take advantage of liquid vinasse in the field of agriculture and industry, and some application was done to use it in the field of construction as a concrete additive.

This research is considered one of the first to use dry vinasse in the concrete field. Generally, there is a lot of research that used sugar waste in the field of concrete (1,13). By studying the use of white sugar as a concrete addition in percentages from 0 to 1% of cement weight. The results showed a slight improvement in compressive strength. The maximum compressive strength was obtained after 28 days at 0.08% [1, 2]. 0.1, 0.2 % sugar of the cement content was added to the brick manufacturing. The results showed that at 28 days, the increase in compressive strength reached by adding 0.1% sugar to 17% and with 0.2% sugar to 9%.[3]

By adding molasse on concrete with various proportions between 0 to 5 % by weight of cement. it is found that at 0.25% molasses, the maximum increase in compressive strength, split strength and flexural strength of concrete occurred. at 90 days, strength increases 10 to 30 % depending on type of mixtures.[4]

By using VSW2016 (vinasse liquid, Sodium Naphthalene Formaldehyde and water) as a concrete admixture. the results showed that, VSW2016 causes noticeable improvement in the compressive strength, splitting strength and flexural strength compared to control mixes. [5,6]

When adding sugar to concrete in the proportions of 0, 0.05 and 0.1%, it was found that, by increasing the doses of sugar the compressive strength increases. at 28 days, the maximum

increase in compressive strength reached 12 % at 0.1 % sugar.[7]

Experimental work on studying the effect of sugar on the strength of concrete at a concentration of 0.0, 0.06, 0.08% by weight of cement content. At 28 days the compressive strength increases 16.02% as compared to concrete without sugar.[8]

By the addition of $H_2O_2$ at different percentages (3% and 5 %) to vinasse to prevent fungal growth and study the effect of adding it on the properties of cement paste. It was obtained that, by increasing the curing time, the compressive strength increases. The strength increases with $H_2O_2$ decreases.[9]

By using Sugar powder content 0, 0.05, 0.075, 0.1, 0.15, and 0.2 % by weight of cement to study the effect of sugar on compressive strength of concrete. The results showed a noticeable improvement in compressive strength at 0.1%, where the increase in compressive strength reaches 15-20%.[10]

By studying the effect of sugar on properties of concrete, the comparison is made between the varying proportions (0, 0.05, 0.1, 0.15, 0.2 and 0.25%) by weight of cement. it was found that, the compressive strength increases by increasing the doses of sugar up to 0.1% sugar. After 28 days the increase in compressive strength reached 12 % at 0.1 sugar.[11]

The durability of concrete was checked by exposed the cubes to acid solution (HCl). The samples of concrete with sugar showed less proportion of weight loss and less loss in strength [12].

## Materials and Methods

Experimentation was done to examine the following:

The important objectives are to study strength properties like compressive strength, splitting strength and flexural strength of concrete and durability properties with dry vinasse as admixture in concrete composition. To study the behavior of concrete with different admixture proportions at 0, 0.2, 0.3, 0.4, 0.5% dry vinasse by weight of cement content.

### Material

Cement: 32.5 grade Ordinary Portland Cement was used; its Specific gravity was 3.15.

Fine Aggregate: Locally available sand passing through 4.75 mm. Its specific gravity was 2.50.

Coarse Aggregate: Locally available machine crushed coarse aggregate has been used. The size of coarse aggregate was chosen for experimentation work is - 20 mm. Its specific gravity was 2.56.

Mixing Water: tap water was used as mixing water.

Admixture: Dry vinasse collected from ESIIC (Egyptian Sugar & Integrated Industries Co.) was used as admixture in concrete composition and it was used at different percentages at 0, 0.2, 0.3, 0.4 and 0.5% from cement weight. Typical properties of them was listed table (1).

Table (1): Typical properties of Dry vinasse [13]

| Parameter | Test Method | Description |
|---|---|---|
| pH | ACAL-APR-08-01 | 5.66 |
| Sulfate | ACAL-APR-21-00 | 4.658 % (wt/wt) |
| Chloride | ACAL-APR-14-00 | -Ve |
| Total sugar | ACAL-APR-33-00 | 12.88 g / kg |

Mixes: Three concrete mixtures were used in the tests with cement content (300, 350 and 400 Kg/$m^3$). The slump was kept at (100-120 mm) for all mixes.

### Concrete Mix Testes

The cubes, cylinders and beams were prepared and cured by immersing in curing tank of tap water.

**Compressive strength test**

Then 9 cubes were taken for each mix (control mix + all test mixes with dry vinasse of different percentages) for compressive strength testing at each test age (28, 90 and 180 days) and the results were averaged for the assessment of compliance.

**Indirect tensile strength test**

**Splitting strength**

3 cylinders were taken for each mix (control mix + all test mixes with dry vinasse of different percentages) for Splitting strength testing at each test age (28, 90 and 180 days) and the results were averaged for the assessment of compliance.

**Flexural strength**

3 beams were taken for each mix (control mix + all test mixes with dry vinasse of different percentages) for Flexural strength testing at each test age (28, 90 and 180 days) and the results were averaged for the assessment of compliance.

**Durability characteristics of concrete**

**Effect of Sulfur Salts on Compressive Strength**

3 cubes for each mix were cured in water for 28 days and then immersed in a solution contains 10% sodium sulfate until 180 days. Compressive strength test was performed on the samples after six months.

**Determination of Sulfate and Chloride Contents**

After crushing specimens of cubes (with cement content 3.5 Kn/$m^3$) which immersion in curing tank of fresh water at 180 days.

## Results

### Effect of dry vinasse on strength

### Compressive strength ($f_c$).

The results of compressive strength of concrete mixes with and without dry vinasse at age 28, 90 and 180 days were shown in Table (2) and Figs. (1, 2, 3). It is found that, the maximum increase of compressive strength occurred at 0.4 % dry vinasse in all age of curing, where it reaches to 57.43%, 45.10% and 32.31% at cement content 300, 350, 400 kg/m$^3$ respectively at 28 days, at 90 days reaches 56.98%, 42.86% and 33.93% at cement content 300, 350, 400 kg/m$^3$ respectively and at 180 days reaches 52.88%, 45.48% and 35.79% at cement content 300, 350, 400 kg/m$^3$ respectively.

Table (2): The results of compressive strength of concrete mixes with and without dry vinasse at age 28, 90 and 180 days

| Doses of admixture / cement | Cement content kg/m$^3$ | Compressive strength ($f_c$) | | |
|---|---|---|---|---|
| | | $f_{c28}$ kg/cm$^2$ | $f_{c90}$ kg/cm$^2$ | $f_{c180}$ kg/cm$^2$ |
| Control | 300 | 249 | 265 | 295 |
| 0.2 % | | 277 | 288 | 327 |
| 0.3 % | | 388 | 410 | 444 |
| 0.4 % | | 392 | 41.6 | 451 |
| 0.5 % | | 344 | 378 | 397 |
| Control | 350 | 286 | 301 | 332 |
| 0.2 % | | 343 | 370 | 394 |
| 0.3 % | | 401 | 427 | 456 |
| 0.4 % | | 415 | 430 | 483 |
| 0.5 % | | 370 | 393 | 423 |
| Control | 400 | 325 | 333 | 366 |
| 0.2 % | | 352 | 375 | 418 |
| 0.3 % | | 405 | 431 | 462 |
| 0.4 % | | 430 | 446 | 497 |
| 0.5 % | | 396 | 419 | 438 |

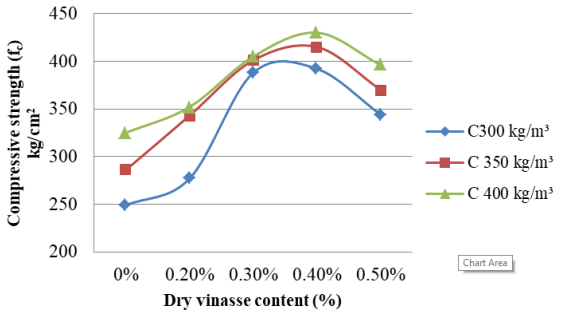



Fig. (1): Compressive strength ($f_c$) at 28 days using dry vinasse

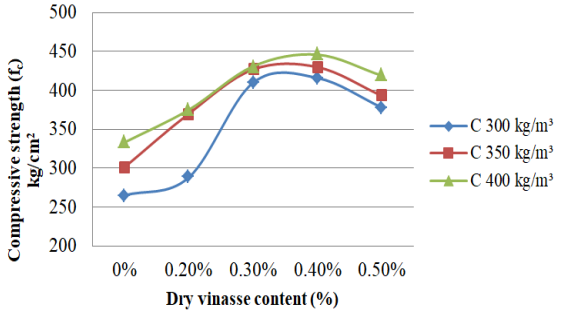



Fig. (2): Compressive strength ($f_c$) at 90 days using dry vinasse

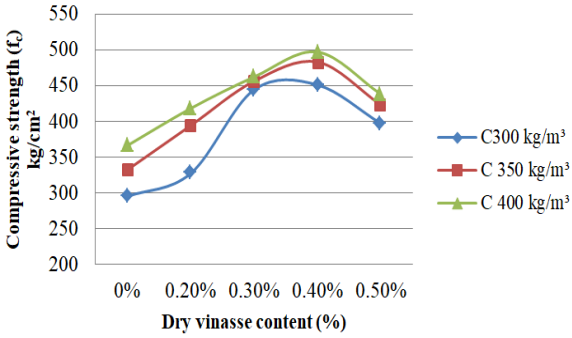



Fig. (3): Compressive strength ($f_c$) at 180 days using dry vinasse

### Indirect Tensile Strength

### Splitting Strength ($f_{sp}$)

Table (3) & Figs. (4, 5, 6) show the results of splitting strength of concrete mixes with and without dry vinasse at ages 28, 90 and 180 days.

It is clear from the results that there has been a noticeable improvement in the splitting strength of the samples to which dry vinasse were added to that of which dry vinasse were not added, for all ages. The highest splitting strength value reaches to 30.3, 32.2, 35.2 kg/cm$^2$ at ages 28, 90, 180 days respectively at cement content of 300 Kg/m$^3$, at cement content of 350 Kg/m$^3$ reaches 32.8, 33.5, 35.4 Kg/m$^3$ at ages 28, 90, 180 days respectively and at cement content of 400 Kg/m$^3$ reaches 33.4, 34.2, 38.7 Kg/m$^3$ at ages 28, 90, 180 days respectively.

Table (3): Splitting Strength (fsp) results of concrete mixes with dry vinasse

| Doses of admixture / cement content | Cement content kg/m$^3$ | Splitting strength $f_{sp}$ | | |
|---|---|---|---|---|
| | | $f_{sp28}$ kg/cm$^2$ | $f_{sp90}$ kg/cm$^2$ | $f_{sp180}$ kg/cm$^2$ |
| Control mix | 300 | 19.9 | 20.7 | 22.7 |
| 0.2 % | | 20.5 | 22.8 | 23.2 |
| 0.3 % | | 27.9 | 28.7 | 30.4 |
| 0.4% | | 30.3 | 32.2 | 35.2 |

| | | | | |
|---|---|---|---|---|
| 0.5% | | 25.7 | 26.8 | 29.1 |
| Control mix | 350 | 21.7 | 24.6 | 25.6 |
| 0.2 % | | 23.7 | 25.4 | 28.9 |
| 0.3 % | | 30.5 | 32.3 | 33.3 |
| 0.4% | | 32.8 | 33.5 | 35.4 |
| 0.5% | | 25.5 | 29.1 | 29.7 |
| Control mix | 400 | 23.1 | 25.3 | 26.3 |
| 0.2 % | | 25.5 | 26.7 | 29.1 |
| 0.3 % | | 31.9 | 33.6 | 34.2 |
| 0.4% | | 33.4 | 34.2 | 38.7 |
| 0.5% | | 29.4 | 32.2 | 33.1 |

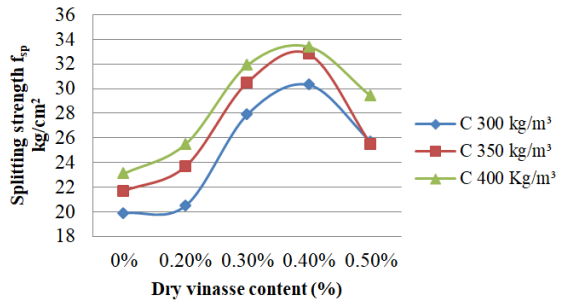



Fig. (4): Splitting strength $f_{sp}$ at 28 days

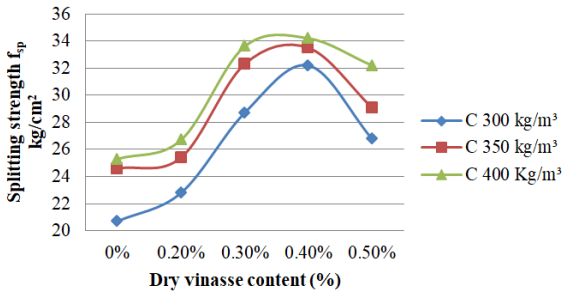



Fig. (5): Splitting strength $f_{sp}$ at 90 days

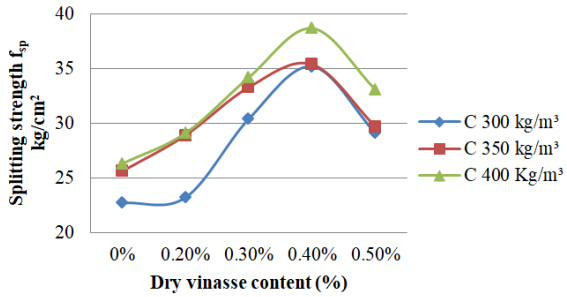



Fig. (6): Splitting strength $f_{sp}$ at 180 days

**Flexural Strength ($f_{cr}$)**

Table (4) & Figs. (7, 8, 9) show flexural Strength ($f_{cr}$) results of concrete mixes with dry vinasse at ages 28, 90 and 180 days.

The effect of dry vinasse on flexural strength is similar to its effect on compressive strength and splitting strength. It increases with the increase in the dose of dry vinasse to 0.4% and then decreases. The highest flexural strength value reaches to 51.0, 53.5, 57.2 Kg/m³ at ages 28, 90, 180 days respectively, at cement content of 300 Kg/m³, at cement content of 350 Kg/m³ reaches 58.2, 63.4, 64.4 Kg/m³ at ages 28, 90, 180 days respectively and at cement content of 400 Kg/m³ reaches 69.4, 72.5, 73.8 Kg/m³ at ages 28, 90, 180 days respectively.

Table (4): Flexural Strength ($f_{cr}$) results of concrete mixes with dry vinasse

| Doses of admixture / cement content | Cement content kg/m³ | Flexural strength $f_{cr}$ | | |
|---|---|---|---|---|
| | | $F_{cr28}$ kg/cm² | $F_{cr90}$ kg/cm² | $F_{cr180}$ kg/cm² |
| Control mix | 300 | 41.6 | 43.3 | 47.0 |
| 0.2 % | | 42.6 | 44.2 | 47.3 |
| 0.3 % | | 50.4 | 53.0 | 57.0 |
| 0.4% | | 51.0 | 53.5 | 57.2 |
| 0.5% | | 49.2 | 50.7 | 53.6 |
| Control mix | 350 | 47.3 | 49.1 | 52.4 |
| 0.2 % | | 51.2 | 54.3 | 55.8 |
| 0.3 % | | 57.5 | 60.6 | 61.6 |
| 0.4% | | 58.2 | 63.4 | 64.4 |
| 0.5% | | 55.8 | 60.3 | 60.2 |
| Control mix | 400 | 50.0 | 53.5 | 57.7 |
| 0.2 % | | 53.0 | 55 | 57.3 |
| 0.3 % | | 64.3 | 68.1 | 70 |
| 0.4% | | 69.4 | 72.5 | 73.8 |
| 0.5% | | 61.4 | 67.5 | 69.3 |

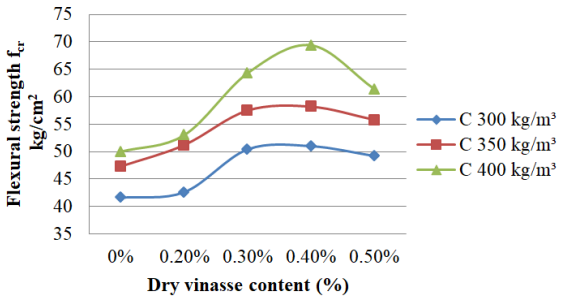



Fig. (7): Flexural strength $f_{cr}$ at 28 days.

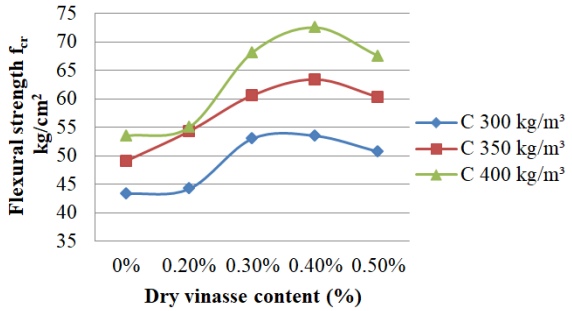



Fig. (8): Flexural strength $f_{cr}$ at 90 days

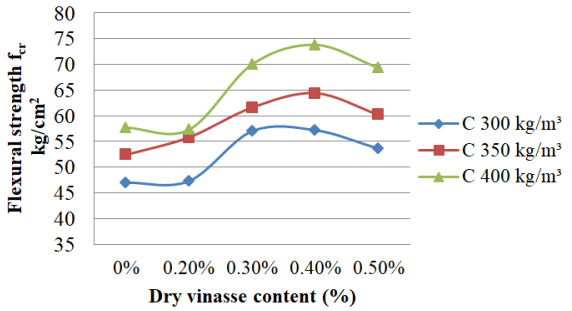



Fig. (9): Flexural strength $f_{cr}$ at 180 days

**Durability Tests Results**

**Effect of Sulfur Salts on Compressive Strength**

By comparing the compressive strength of the samples cured with water after 180 days, with those exposed to (10% $SO_4$ solution) until testing time by using dry vinasse for all cement contents. as shown in Table (5) and Figs. (10, 11, 12).

The results showed that, with dry vinasse, there is a noticeable improvement in concrete degradation resistance due to immersion in a solution of 10% $SO_4$ (14). Where the maximum reduction in compressive strength reaches 10.80 % for control mixes and 8.45% at 0.5 % dry vinasse at cement content of 400 kg / m³.

Table (5) Results of compressive strength tests at (180) days using dry vinasse additives exposed to 10% of $SO_4$.

| Doses of admixture / cement content | Cement content Kg/m³ | Compressive strength at 180 day exposed to $SO_4$ | | |
|---|---|---|---|---|
| | | $f_{c180}$ kg/cm² | $f_{c180(SO4)}$ kg/cm² | $f_{c180(SO4)}/f_{c180}$ % |
| Control | 300 | 295 | 263 | 89.20 |
| 0.2 % | | 327 | 325 | 99.39 |
| 0.3 % | | 444 | 420 | 94.60 |
| 0.4% | | 451 | 441 | 97.78 |
| 0.5% | | 397 | 377 | 94.96 |
| Control | 350 | 332 | 310 | 93.37 |
| 0.2 % | | 394 | 390 | 98.98 |
| 0.3 % | | 456 | 446 | 97.81 |
| 0.4% | | 483 | 463 | 95.86 |
| 0.5% | | 423 | 419 | 99.05 |
| Control | 400 | 366 | 334 | 91.26 |
| 0.2 % | | 418 | 400 | 95.69 |
| 0.3 % | | 462 | 454 | 98.27 |
| 0.4% | | 497 | 476 | 95.77 |
| 0.5% | | 438 | 401 | 91.55 |

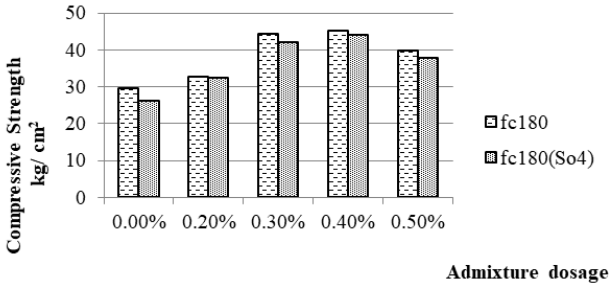



Fig (10): Comparison between the compressive strength of the samples exposed to $SO_4$ at 180 days with those cured with water until testing time using dry vinasse additive at cement content 300 Kg/m³

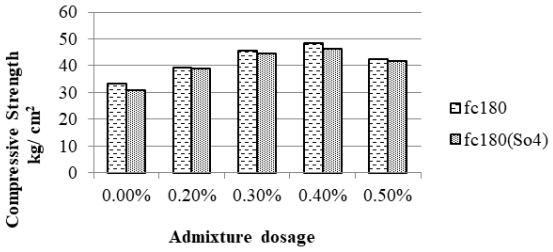



Fig (11): Comparison between the compressive strength of the samples exposed to $SO_4$ at 180 days with those cured with water until testing time using dry vinasse additive at cement content 350 Kg/m³

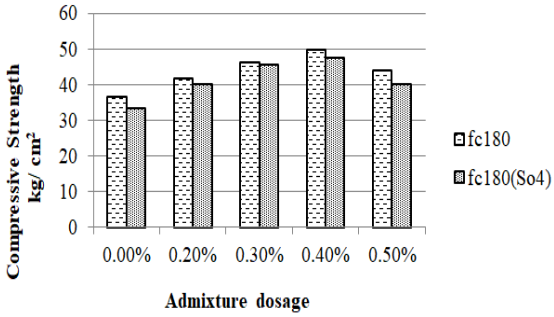



Fig (12): Comparison between the compressive strength of the samples exposed to $SO_4$ at 180 days with those cured with water until testing time using dry vinasse additive at cement content 400 Kg/m³

**Determination of Sulfate and Chloride Contents**

The percentage of sulfate and chlorides for the test samples after 180 days according to Egyptian specification requirements (15), as the maximum percentage of sulfate and chlorides reached to 0.31 % and 0.147 % respectively by weight of cement at 0.4% dry vinasse as shown in Table (6).

Table (6): Results of sulphate and chloride contents for concrete mixtures by using dry vinasse additives with cement content 350 Kg/m3.

| Dose of Admixture | Sulfate content By weight | Limits (Max.) (Egypt Code) | Chloride content By weight | Limits (Max.) (Egypt Code) |
|---|---|---|---|---|
| control | 0.16 % | 4 % | 0.07 % | 0.15% |
| 0.2 % | 0.22 % | | 0.071 % | |
| 0.3 % | 0.24 % | | 0.074 % | |
| 0.4 % | 0.31 % | | 0.147 % | |
| 0.5 % | 0.17 % | | 0.12 % | |

## Conclusions

The main conclusions derived from this study are as follows:

- The compressive strength increases as the dose of dry vinasse increases as compared to ordinary concrete up to 0.4% dry vinasse then decreases.
- Dry vinasse causes noticeable increase in flexural strength and splitting strength compared to control mixes.
- Concrete with dry vinasse as additive showed more degradation resistance for the samples exposed to solution of 10% sodium-sulfur.
- The maximum reduction in compressive strength reaches 10.80 % for control mixes and 8.45% at 0.5 % dry vinasse at cement content of 400 kg / $m^3$.
- The most favourable dose of dry vinasse is 0.4% dose.

## Funding sources

This research received no external funding.

## Conflicts of interest

There are no conflicts to declare.

## References

[1] Abalaka, AE, Effects of Sugar on Physical Properties of Ordinary Portland Cement Paste and Concrete, AUJT, 3, 14 (2011) 225-228.

[2] Abalaka, AE, Comparative Effects of Cassava Starch and Simple Sugar in Cement Mortar and Concrete, ATBU Journal of Environmental Technology, 1, 4 (2011) 13-22.

[3] G.L. Oyekan , Effect of admixtures on the compressive strength of sandcrete blocks, Journal of Engineering and Applied Sciences,3,6 (2008) 451-454

[4] Aftab Aalm , Parveen Singh , Experimental Study on Strength Characteristics of Cement Concrete by Adding Sugar Waste, International Journal of Enhanced Research in Science, Technology & Engineering , 5, 7, July (2016) 33-40.

[5] A. Megahed Ahmed, Mohamed M. A, Omar A, F. and Shawky M. H. Improvement of the concrete characteristics by using sugar industry wastes (vinasse), Journal of Engineering Sciences, Faculty of Engineering, Assiut University,46, 2 (2018) 142 – 159.

[6] Megahed Ahmed, Mohamed M. A, Omar A, F. and Shawky M. H., Characteristics and Durability of Concrete Containing Sugar Industry Wastes (Vinasse) Exposed To Aggressive Environmental Conditions, Journal of Engineering Sciences, Faculty of Engineering, Assiut University,46, 3 (2018) 282 – 298.

[7] Giridhar.V, Gnaneswar. K and Kishore Kumar Reddy. P, Effect of Sugar and Jaggery on Strength Properties of Concrete, The International Journal of Engineering and Science, 2,10 (2013) 1-6

[8] Jaibeer Chand, Sangeeta Dhyani., Effect of Sugar on the Compressive Strength of Concrete, International Journal of Advanced Technology & Engineering Research (IJATER), 5, 4 (2015) 5-7.

[9] Ayman M.K, Samah A.S and Samah A.R.M, Physical Chemical, mechanical and mycological properties of cement pasted incorporating vinasse, chemistry research, journal, 4, 3 (2019) 75-85

[10] Yogesh. R. Suryawanshi, Pankaj N. Bhat, R. R. Shinde, S. B. Pawar& Namrata Mote, Experimental Study on Effect of Sugar Powder on Strength Of Cement, International Journal of Research in Engineering & Technology, 2,4, (2014) 249-252.

[11] Abhijeet Kawade, I. K. A. B. K., "Experimental study of Effect of Sugar on Properties of Concrete". Journal of Structural & Transportation studies, 2, 1, (2017) 1-8.

[12] Lakshmish T P, Nikhil T R, Naveen Kumar H S, Effect of sugar on Strength and Durability Characteristics of HVFAC Pavements, International Journal of Engineering Research & Technology, 8, 11, Nov. (2019) 288-291.

[13] A. Megahed Ahmed, Mohamed A. A and A.E.Mahmoud, Uses of Dry Vinasse as A Friendly Environmental Material to Improve Properties of Cement Mortar and Concrete, Journal of Engineering Sciences, Faculty of Engineering, Assiut University,48, 3, (2020) 396– 405.

[14] Omer F., said H., Amal B. and shawky M. H., Using sugar industry wastes (vinasse) as a plasticizer concrete admixture enhancing durability consideration, international conference innovation building materials. Egypt (HBRC) 2014.

[15] Directory of laboratory tests for concrete material (ECP 203-2018).