IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 17, Issue 1 Ser. V (Jan - Feb 2020), PP 36-43
www.iosrjournals.org

Evaluation of Strength and Durability Concrete Properties using Teff Husk

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Abstract: *In Ethiopia Teff (Eragrostis teff) is an important food grain where it is used to for the preparation of Injera which is the major food used in Ethiopia. Teff milling generates a by-product known as Teff Husk (TH). Around 22 percent husk is generated during milling. As the Teff husk is organic waste which is obtained after harvesting in large quantity. Among this small quantity is used for feeding the cattle's, rest is thrown or burnt which causes an environmental problem. Therefore, in this research we have made an attempt to study the effect of Teff husk on mechanical and durability properties of concrete with different percentages (5%, 10%, 15%, 20%, 25% and 30%) of TH with sand replacement by keeping constant w/c ratio of 0.45. Properties like Compressive strength, split tensile strength, flexural strength, unit weight, and Water absorption properties are evaluated at different ages of harden concrete 7, 14, 21 and 28 days. From the experimental results, it was observed the compressive strengths and unit weights of the concrete ranged between 28.76MPa and 22.38MPa and between 2296.38 and 2218.64 kg/m3 respectively. In addition, flexural strength varied between 0.48 and 0.4 MPa. In conclusion, the results revealed that the unit weight and compressive strength decreased with an increase in percentage Teff husk by 10 %. Teff husk can be used in the preparation of concrete*
Key Words*: Teff Husk, compressive strength, split tensile strength, water absorption, density.*

Date of Submission: 27-02-2020 Date of Acceptance: 06-03-2020

I. Introduction

Teff is a primary food source for millions of people in Ethiopia, according to food and agriculture organization of the Ethiopia data shows that the production of Teff is increasing annually by 10.42 % on an average[1]. Increasing demand of the building materials had come into the concern of public and related industries. The issue is not only the chronic shortage of building materials but also the great impact to the environment and land degradation in search of virgin construction materials like sand.

Use of rice husk on fresh and harden concrete properties was studied by [2] and they observed improvement in workability and found decreased in compressive strength with increase in percentage use of rice husk and also affirmed Rice husk cannot be used more than 12.5% replacement of sand.Groundnut shell replacement by fine aggregate at 0-100% replacement levels was carried out by [3,4]observed that groundnut shells can be replaced by 25% to produce lightweight concrete compared to conventional concrete and percentage of water absorption was high compared to conventional concrete and can be used where low stress in concrete is required. Oyster shells replacement was done by sand up to 20% and found there was no reduction in compressive strength[5]. Pineapple leaf fibers were also used to improve tensile strength with 0.09 to 0.30 mm diameter and 35 mm length, fibres were used up to 30% by volume with a composite of lingo-cellulosic fibers with 10% increment gradually and fibers were placed parallelto the tensile axis, the tensile strength and elastic modulus were increased by 2.70 and 5.41 times respectively for 30 % composite[6].The properties of concrete with partial replacement of cement with Rice Husk Ash (RHA), Fly Ash and Eggshell with different combinations were used to study the Compressive strength and water absorption at 28 days. The results obtained by them showed 60% increment in strength with RHA alone at 5 % replacement. The strength was not changed when concrete is done with different combinations[7,8]

Paper review on use of solid waste in building materials[9] and they classified wastes into two categories as organic and inorganic (paper, plastic, glass, metal and others), it has stated that organic waste was 46%. The organic and inorganic materials can be used in a various form in concrete as partial replacement of aggregates, cement or in terms of reinforcing steel with fibers to increase the tensile strength of concrete. Optimum utilization of waste materials from solid waste and industrial plants, powerhouses, colliery pits, demolition sites, household, the organic waste such as bagasse, wheat husk, groundnut shell, sisal, cotton stalk, vegetable residues can be used in some construction activities as a green concept. Waste materials such as plastic, fly ash, recycled aggregates, GGBS, silica fume, rubber waste can be used as partial replacement of cement or aggregates to improve the internal structure of concrete which can be used for the construction of buildings or road pavements, particle boards, insulation boards, acid proof cement, polymer composite cement, bricks.

The agricultural wastes such as rice husk ash, palm oil fuel ash, sugar cane bagasse ash, wood waste ash, and bamboo leaf ash and corn cob ash can be used in the construction industry as a supplementary cementitious material (SCM). These ashes from various agricultural wastes contain silica which helps in the reaction of cement when added with water to form CSH. By using this ash in different percentages strength of concrete can be increased and used up to achieve 61 MPa at 90 days[10].

From the background studies, it can be justified concrete properties can be alter by the addition of assorted agricultural (organic) and industrial waste. Hence, we have postulated that there would be change in concrete properties in strength as well in density of concrete. Keeping this in mind an attempt was made to study the following properties of concrete Compressive Strength, split tensile strength, Flexural strength of concrete water absorption and unit weight of concrete using Teff husk with partial replacement of sand by volume.

II. Material And Methods

Experimental work is conducted in Adama Science and Technology Ethiopia using locally available materials. All the experimental work was carried out as per ASTM. The experimental work includes casting and testing of 189 Cubes (150 mm x 150 mm x 150 mm), 21 cylinders (150 x 300 mm) and 21 Prisms (500 x 100 x 100 mm). Seven groups of specimens were casted by replacing sand with Teff husk up to 30 % with 5% successive increment with constant w/c ratio 0.45.

Material Properties

Local available Cement 32.5 grade was used, the fine Aggregate passing through 4.75mm was taken to study the particle size distribution and it was observed the particle size were more concentrated between 1.18 - 0.3 mm. figure-1 shows the fine aggregates particles are not uniformly distributed to fill the voids in the concrete.

Properties of Fine Aggregate (FA)

Fineness modulus	=	2.88
Specific gravity	=	2.68
Water absorption	=	0.86%
Silt or clay content	=	0.5%
Bulk density	=	1520 kg/m^3

Coarse Aggregate (CA)

Grade -2 (10-20 mm aggregate size) was used to study the grain size distribution and presented in figure 2

Properties of Coarse Aggregate

Fineness Modulus	=	5.12
Specific gravity	=	2.7
Water absorption	=	1.12%
Impact value	=	11.76%
Bulk density	=	1440kg/m^3.

Water

Portable tap water from laboratory is used for mixing and curing of water used for both mixing and curing.

Teff Husk (TH)

The Teff husk color varies from ivory to dark reddish- brown purple; the grain is oval shaped with size 0.9–1.7 mm (length) and 0.7–1.0 mm (diameter). The individual grain mass is generally in the range of 0.2–0.4 [11]. The chemical composition of teff seeds[12]. 100 grams teff husk sample were taken to study the properties such as grain size, specific gravity, and water absorption. Figure 3 shows the teff Husk and figure 4 shows the grain size distribution with percentage passing.From figure 4, it’s observed that TH is non-uniform distribution and there is a sharp deepen in the curve which indicates that particle size of 1.2 mm of lesser percentageand later there is sudden increment in the sample which clearly indicates that presence finer size particles. The Teff husk size ranges from 0.6 – 1.18 mm, Dry density Teff husk 0.151 kg/cm^3, Specific gravity of Teff husk 0.15 and Water absorption= 90 % for 3 hours

Super Plasticizer

As TH is an organic material, and contains water in it hence, High range water-reducing admixture (HRWA) from Fosroc Chemicals India Limited, Bangalore of type Conplast SP- 430 has been used.

Mixing method

Teff husk is organic material hence absorbs water 90% in 3 hours from the initial observation. Hence, it was soaked for 3 hours before using it in the dry mix for concrete. Mix proportion for one cubic meter is shown in table 1.

Casting and Curing

The ingredients of cement, coarse aggregate, fine aggregate and wet teff husk was mixed in the dry state until uniform color mix as per the mix design requirements later admixture and water are added and mixed again until uniform paste is observed. The moulds are greased with lubricant material to the inner surface of the mould to prevent the sticking of cement concrete to mould; the fresh concrete was casted by tamping the materials in three layers using the tamping rod of 25 mm at a height of 50 mm. These specimens are allowed to set in the moulds for 24 hours and these specimens are de-molded, immersed in curing tank at the different age of concrete for determining the various parameters of concrete.

Compressive Strength of Concrete

The compressive strength of concrete is determined by specimen size 150 mm × 150 mm × 150 mm cubes the compressive strength of concrete is determined by the compressive testing machine of capacity 2000 KN in a concrete laboratory. Setup for compressive strength is shown in figure 5; the specimen is loaded up to failure at a rate of 40 KN/s. The weight of the concrete sample was recorded before conducting the test for reference in order to determine the unit weight of concrete. Compressive strength is calculated using:

$$Fc = P/A \qquad (1)$$

Split Tensile Strength for Concrete

The split tensile strength of concrete is determined by casting cylindrical concrete specimens by placing the specimens as shown in Figure 6. The load was applied at a uniform rate of 40 KN/sec till the specimen is failed along the vertical diameter. The load at which the specimen ultimately fails is noted and split tensile strength is calculated by:

$$T_{sp} = 2P/\Pi DL \qquad (2)$$

Test for Flexural Strength

Plain concrete prism of size 100 x 100 x 500 mm is casted to determine the flexural strength of concrete for single point load. The modulus of rupture is computed by

$$F = M/Z \qquad (3)$$

Water Absorption

The water absorption values for various mixtures of concrete were determined on 150mm x 150mm x 150mm cubes. Equation 4is used to find water absorption value of concrete specimens is given by:

$$SWA = [(Ws - Wd) / Wd] \times 100 \qquad (4)$$

Unit Weight of Concrete

The density of concrete is calculated by:

$$Dc = (Mc - Mm) / Vm \qquad (5)$$

III. Results and Discussions

Slump Test

The slump values for different percentage of replacement for Teff husk is shown in Figure 7. Form the results, it's observed that the slump value increases with the increase in the percentage of Teff husk. This is due to the smooth surface of teff husk and low specific surface area which makes the concrete easy to work.

Unit Weights of Samples

Table 2 and figure 8 gives the details about variation in unit weight of samples for different percentage of Teff Husk.

Cube Compressive strength

The compressive strength of concrete mixes made with and without Teff husk was determined on 7th, 14th, 21st and 28 days of curing. Table 3 gives the details about variations in the compressive strength of concrete samples for different percentage of Teff Husk.

From table 3, figure 9 and 10, it's observed that compressive strength of concrete is slightly increased with the replacement of TH at 10% later there is decrease in strength. This increase in the strength may be due to the intial water absorption of TH. From the figure 11, its observed there is slightly increase in unit weight of concrete with increase in compressive strength.

Split tensile Strength

The splitting tensile strength of concrete results is tabulated in Table 4 at different ageof concrete as shown below. Figure12 shows the result for 28 days age of concrete.From figure 12, is found to be increased up to 1.5 % for 10% replacement of TH and also found negligible difference with compared to conventional concrete.

Flexural Strength

The flexural strength test results of controlled and teff husk concrete at 28 days are tabulated in table 5 and also presented in Figure13.

As the TH is longer in size, hence it was expected to increase the flexural strength, but from experimental observation results shown in figure 13 it is found to be decrease in flexural strength. This may be due to bonding between mortar and TH as Teff husk is surface texture is smooth in surface.

Water Absorption

Water absorption test was done with controlled and Teff husk concrete for 28 days. Averages of 3 specimens were taken into consideration. Results are presented in table 6and figure 14. From the result it is observed that water absorption is increased with increased in percentage of TH, this is due to the alternate dry and wet of Teff husk. Addition of 10% Teff husk is within the permissible limit of code book.

IV. Conclusions

The experimental work was conducted with sand replacement by the volume up to 30% with linear increment of five percent. Studies were carried on the structural properties of concrete in terms of compressive strength, flexural strength, and unit weight and water absorption by casting cube, cylinder andbeams specimens. Based on the results, the following conclusions are drawn:

1- The workability of concrete was increased up to 13 % with increase in TH up to 30% replacement of sand by TH.
2- Unit weight of concrete was decreased with increase in the percentage of TH up to 20% but the compressive strength of concrete was reduced parallel.
3- Test results showed positive response up to 10 % replacement with an increase in compressive strength up to 3 % for 28 days.
4- Split tensile strength and flexural strength of concrete was also found to be lower than controlled specimen for 28 days by 9% but was found to be increased up to 1.5 % for 10% replacement of TH and also found negligible difference with compared to conventional concrete.
5- Water absorption was high in TH concrete up to 55 % with 30% replacement of sand by TH as compared to that of controlled concrete.
6- The overall behavior of Teff Husk concrete with that of controlled specimen closely resembles that of equivalent strength up to 10 % replacement by Teff Husk.

Acknowledgments

This research described herein was technically supported by the Adama Science and Technology University Adama - Ethiopia

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Table no 1- Mix proportion and materials required for Cube strength 25 MPa in Kg/m^3

Water	**Cement**	**FA**	**CA**
193.77	425.78	544.01	1296.71
0.45	1.00	1.27	3.04

Table no 2 -Unit weights of controlled and TH specimens

Mix	M1	M2	M3	M4	M5	M6	M7
TH %	0	5	10	15	20	25	30
Age	3-3 samples; unit weights (kg/m^3)						
7 Avg	1982.50	1860.95	1780.47	1642.64	1584.82	1490.18	1416.07
14Avg	2124.11	1973.06	1889.04	1745.31	1685.13	1586.94	1510.48
21Avg	2265.72	2130.01	2041.03	1889.04	1805.49	1722.42	1661.52
28Avg	2360.12	2242.35	2171.64	2053.87	2006.54	1935.92	1888.34

Table no 3- Cube Compressive Strength of controlled and TH specimens

Mix	M1	M2	M3	M4	M5	M6	M7
TH %	0	5	10	15	20	25	30
age	3-3 Samples Compressive Strength (N/mm²)						
7 Avg	20.10	20.50	20.70	19.50	18.49	17.29	16.48
14 Avg	27.00	27.54	27.81	26.19	24.84	23.22	22.14
21 Avg	28.50	29.07	29.36	27.65	26.22	24.51	23.37
28 Avg Avg	30.15	30.60	30.90	29.10	27.60	25.80	24.60

Table no 4- Split tensile strength of controlled and TH specimens

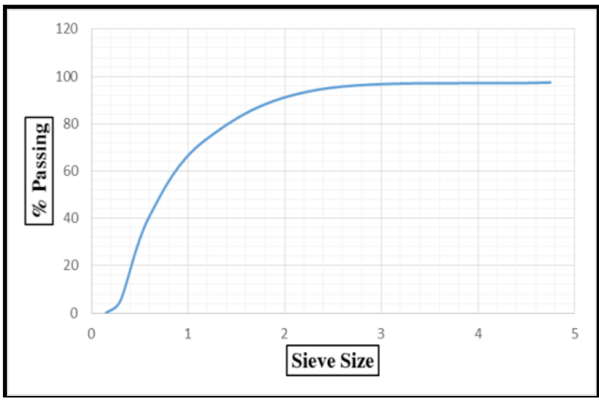
Mix	M1	M2	M3	M4	M5	M6	M7
TH (%)	0	5	10	15	20	25	30
Test age (days)	3-3 Samples Split Tensile Strength (N/mm²)						
28-Avg	3.83	3.87	3.89	3.78	3.68	3.56	3.47

Table no 5- Flexural Strength of Grade controlled and TH specimens

Mix	M1	M2	M3	M4	M5	M6	M7
TH %	0	5	10	15	20	25	20
age	3-3 Samples Flexural Strength (N/mm²)						
28 days	0.48	0.47	0.46	0.44	0.43	0.42	0.4

Table no 6 -Water Absorption of controlled and TH specimens

Mix	M1	M2	M3	M4	M5	M6	M7
TH%	0	5	10	15	20	25	20
28 days	3.12	3.46	3.98	4.25	4.77	5.66	6.98



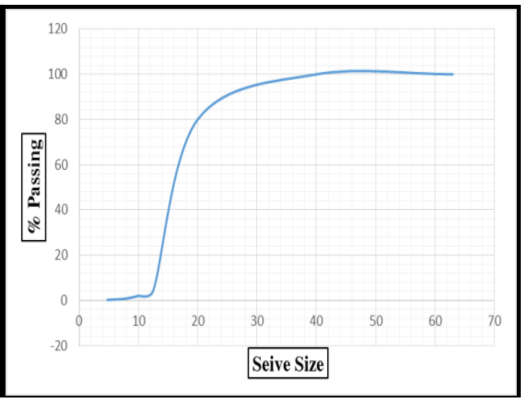


Fig1. Grain size distribution of fine aggregate .***Fig 2.*** Grain size distribution of coarse aggregate.

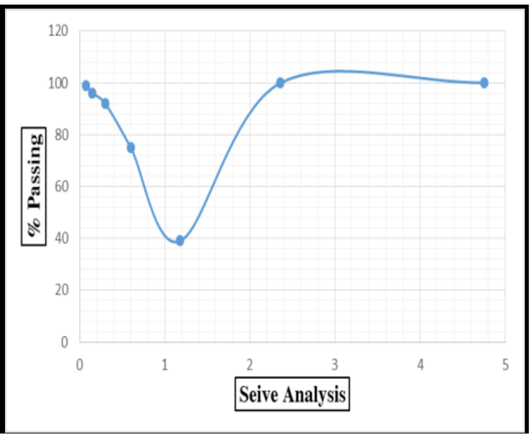
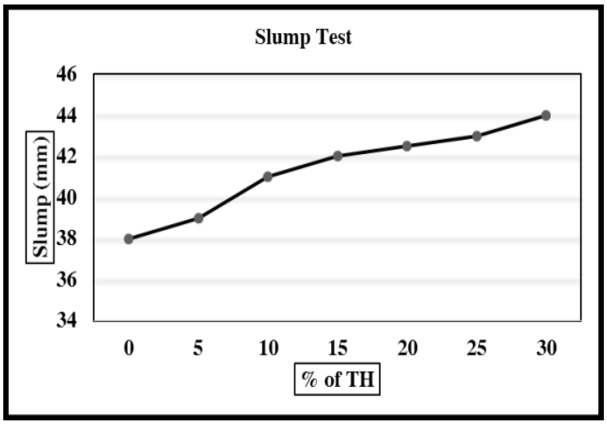


Fig 3.Teff Husk ***Fig 4.***Sieve analysis for teff husk

Fig 5. Compressive strength of cube.**Fig 6.**Setup for split tensile strength test



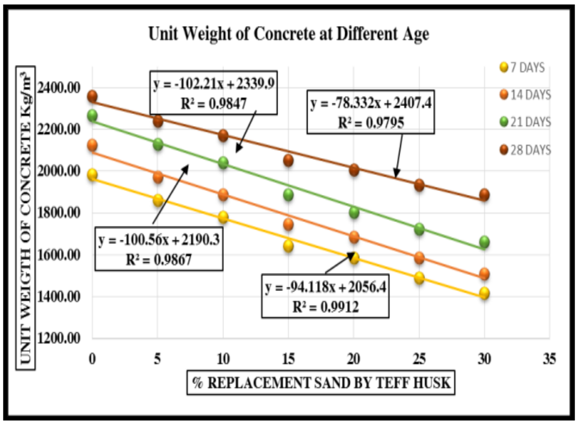
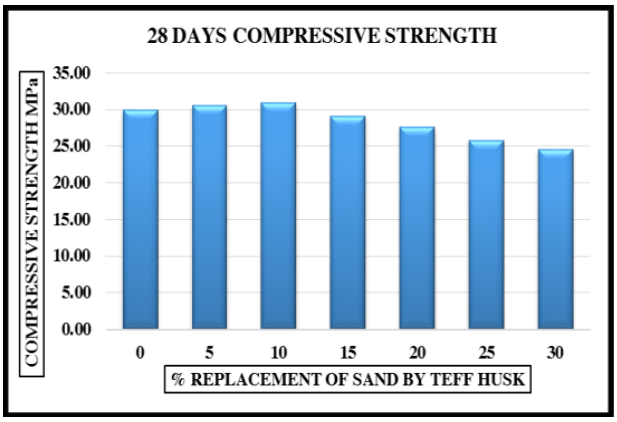


Fig7. Workability of fresh concrete. **Fig8.**Unit weight of concrete.



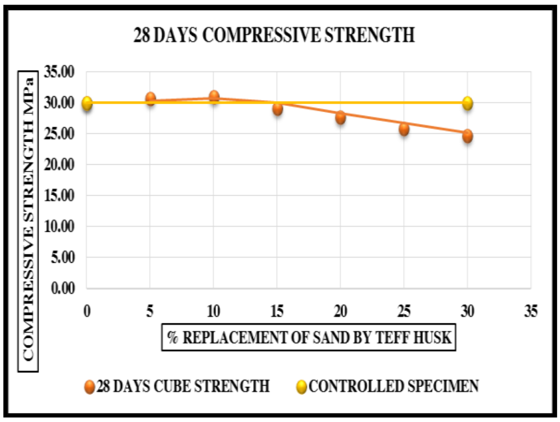
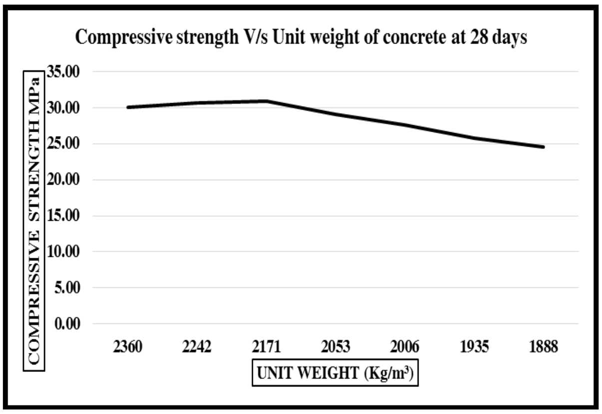


Fig 9. Compressive strength of cube for concrete 28 days **Fig10.**Comparison of compressive strength of teff husk concrete and controlled specimenat 28 days



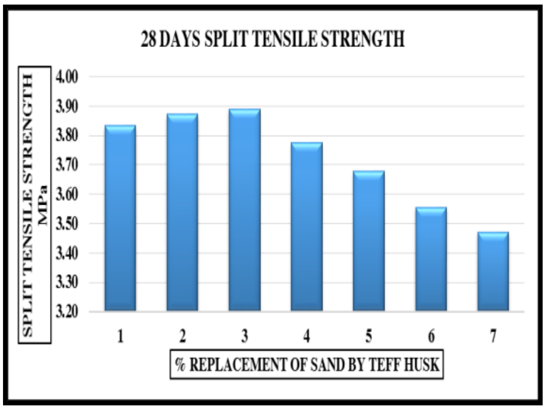
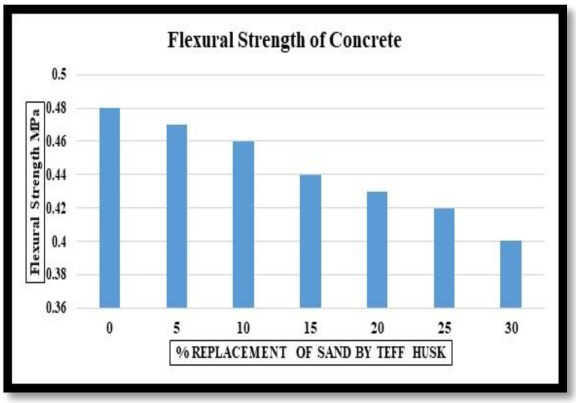


Fig 1.1 Compressive strength with unit weight of concrete at 28 days **Fig 12** . Split tensile of concrete for 28 days



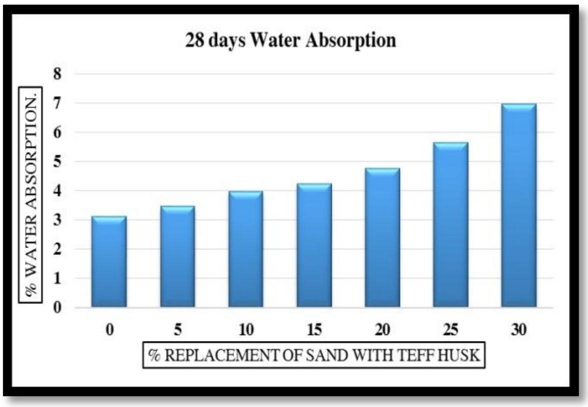


Fig 13. Flexural strength of for different % replacement of TH **Fig 14.**Percentage of water absorption with different % of TH

Kumar Shantveerayya. "Evaluation of Strength and Durability Concrete Properties using Teff Husk." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 17(1), 2020, pp. 36-43.