International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 05 | May 2022 www.irjet.net p-ISSN: 2395-0072

Study on Strength Development of High Strength Concrete Containing Steel fibers, Silica fumes and Wheat Straw ash

Shubham Patidar[1], Dr. H. K. Mahiyar[2]

[1]M.E Transportation Engineering, S.G.S Institute of Technology and Science Indore (M.P)
[2] Prof. & Head, CE&AMD, S.G.S Institute of Technology and Science Indore (M.P)

Abstract - *In this experimental study the properties of high strength concrete has been studied by adding wheat straw ash in different percentage to the weight of cement. The main objective of this experimental study is to find out the mechanical properties which include (both 7 and 28 days) split tensile and flexural strengths of concrete mix. In this mix, In addition to normal materials, cement is replaced by optimum quantity to silica fumes (i.e. 7.5%), steel fibers (i.e. 1%). Then the cement content was replaced by wheat straw ash (WSA) with 5%, 10%, 15% respectively (by weight of cement). For this purpose, the experiments were carried out on M60, M70 and M80 grade of concrete. For all grades of concrete (i.e. M60, M70 & M80) we found that replacement of 5% cement with wheat straw ash gives maximum split tensile & flexural strength (both 7 & 28 days), however with even 15% replacement of cement by wheat straw ash we get all strengths within targeted range. Hence it can be concluded that a 15% replacement of cement with wheat straw ash is very useful both in increasing the strength properties, reducing the cost & dead load of structures and proper utilization of waste material and reducing the carbon emission.*

Key Words: Steel Fibres, Silica fumes, High Strength Concrete, Split Tensile Strength, Flexural Strength, Wheat Straw Ash.

1.INTRODUCTION

Concrete is very useful, construction material that can be used in various applications. In most of the construction concrete is the main material. When a structure is constructed, the most important consideration is to make it safe, strong and economical. Also, the most important object is to build a structure that is cost-effective. Cement is the primary binding material in concrete, which provides strength and durability to the structure. Now a days, concrete is modified with the use of several additives whose primary function is to increase the concrete's strength and durability, such as fly ash, silica fume, and steel fibres. These are the materials that enable concrete to provide greater strength and durability. Rice Husk Ash, sewage sludge ash and oil shale ash etc. are also new supplementary cemetitious material that improves strength and durability of concrete. Other than these, wheat straw ash (WSA) has also been found to be an affective pozzolanic material.

Silica fume is a byproduct of the manufacture of silicon metal or silicon alloys in an electric arc furnace. Silica fumes help in the improvement of concrete's mechanical properties as well as its durability. These days, cost and environmental factors are very important in every construction activity. In general, the use of fibers along with Silica Fume in concrete has been proved to be enhancing the characteristics of concrete. Steel fiber reinforced concrete is a castable or sprayable composite material made up of hydraulic cements, fine aggregate & coarse aggregates and discrete rectangular cross-section steel fibers distributed randomly throughout the matrix. Steel fibers make concrete stronger by reducing tensile cracking.

Wheat straw waste is a major agricultural by-product obtained from wheat production, which causes environmental pollution because the farmers burn it directly in open fields. When wheat straw waste is properly burnt under controlled situation it gives cementing properties and that can be used as supplementary cementing material. The resulting ash contains higher percentage of silica. The particles of ash are also finer as compared to cement, therefore it is considered as supplementary cementing material. The advantage of using wheat straw ash in concrete as cement replacement material in concrete has revealed that Wheat straw ash increases compressive strength when it was replaced by 5% cement. Researchers are also investigating on the durability aspects of concrete while using wheat straw ash as replacement material because durability is one of the important properties of concrete. It was found that durability is improved due to the pozzolanic and filler property of Wheat Straw Ash in concrete. Additionally, researchers also utilizes wheat straw ash as filler material in concrete because of fineness of particles. Compressive strength of concrete is enhanced by the fine aggregates which was replaced by wheat straw ash.

2. MATERIALS USED

Cement – OPC cement grade 53 is used for this experimental study various laboratory test were conducted on cement and tabulated in Table-1. Cement used in this study was free from any lumps and was in good condition.

Table -1: Laboratory test results conducted on cement

Specific Gravity		3.14
Setting Time (min)	**Initial**	33
	Final	185
Fineness		97%
Consistency		32%
Soundness		1 mm
Compressive strength (7 days)		39.83 MPa
Compressive strength (28 days)		55.32 MPa

Fine Aggregates – Locally available artificial sand which is passing through 4.75 mm sieve was used. Specific Gravity of fine aggregates is found to be 2.75. Water Absorption of fine aggregate was found to be 1.21%.

Coarse Aggregates – Angular Coarse aggregate is used with maximum size of 20 mm. Specific Gravity of coarse aggregate was found to be 2.86. Water Absorption of coarse aggregate was found to be 0.50%.

Silica Fume – Silica Fume is a by-product resulting from the high purity quartz with coal in electric arc furnaces in manufacturing of ferro silicon and silicon metal. Main ingredients of Silica Fume is silicon dioxide which is very fine and spherical in shape. Specific Gravity of Silica Fume used was found to be 2.25.

Steel Fibers – Hooked end , long straight fibers with aspect ratio of 50 are used . The diameter and length of steel fibers is 1 mm and 50 mm respectively. Bundle of steel fibers is taken from market and cut according to required length.

Wheat Straw Ash – Wheat Straw ash is dark grey in colour. The small sized particles plays an important role in filling voids in the concrete, hence it produce dense and durable concrete. Wheat straw ash has pozzolanic properties, means it can react with lime to form a cementanious compound. Specific gravity of wheat straw ash is found to be 1.51.

Water – Portable water is used for mixing as well as for curing purposes. Water used for this experiment study is free from all impurities.

Super Plasticizers – Super Plasticizers is high range water reducer. Use of super plasticizers in concrete can improve the mechanical properties of concrete. In addition to that, it is necessary to use super plasticizers in concrete because concrete need higher water contents, for proper mixing & compacting.

3. OBJECTIVES OF THE STUDY

The use of waste material like silica fume, fly ash, GGBS etc. in concrete is common now a days. This research aims to use wheat straw ash which is an agricultural waste in concrete to make concrete economical and reduce the environmental problems. In this experimental study we have designed high grade concrete using agricultural waste. Following are the parameters of study:

- To design high grade concrete namely (M60, M70 & M80) without any admixture.
- To determine the split tensile and flexural strength of concrete for getting the optimum dose of silica fume and steel fiber to be used in high grade concrete.
- To replace cement with waste material like silica fume & wheat straw ash. Additional strengthening is done by adding steel fibers.
- To determine the split tensile and flexural strength (7 & 28 days) of concrete using the optimum dose of silica fume and steel fiber with various percentage replacement of wheat straw ash (5%, 10% & 15%).
- Cost analysis of normal concrete and concrete with additives (silica fumes, steel fibers and Wheat straw ash).

4. METHODOLOGY

The ingredients used in the study namely cement, fine & coarse aggregates, silica fume, steel fibers, wheat straw ash and water were collected from various sources. The laboratory tests on various ingredients were conducted in the laboratory of the institute. After testing of various ingredient the trial mixes of M60, M70 & M80 were designed using IS 10262-2019. To find the optimum dose of two different admixtures namely silica fume and steel fiber a trial studies on M60 grade of concrete was done. The percentage of silica fume used was 5%, 7.5% & 10% while the percentage of steel fibers was 0.5%, 1% & 1.5%.
After getting optimum doses of silica fume and steel fibers we prepared mix design for M60, M70 & M80 grade of concrete using wheat straw ash. In this work for M60, M70 & M80 grade concrete, cement is replaced by optimum dose of silica fumes i.e. 7.5% by weight of cement, wheat straw ash is replaced with 5%, 10% and 15% by weight of cement & optimal quantity of Steel fibres i.e. 1% weight of cement was added additionally. In this study firstly calculated quantities of cement, sand, aggregates, water, silica fume, wheat straw ash, steel fibers and super plasticizers were weighted according to the mix design ratio of 1 : 1.52 :

2.82 for M60 grade of concrete with water cement ratio of 0.28, mix design ratio for M70 grade is 1 : 1.59 : 2.94 with water cement ratio 0.29 and similarly for M80 grade ratio of mix design is 1 : 1.39 : 2.58 with water cement ratio 0.26. Cylinders (150 mm Dia. 300 mm height) and Beams (100 mm x 100 mm x 500 mm) were casted and tested in compression testing machine at the age of 7 & 28 days to get Split tensile & flexural strength of concrete.

5. RESULTS

- **Determination of optimum dose of silica fumes and steel fibers:**

Table-2 shows 7 & 28 days compressive strength of M60 grade concrete for different percentage of silica fumes. Figure 1 shows the variation in compressive strength of M60 grade concrete with percentage of silica fumes-

Table -2: Determination of optimum dose of silica fumes

S.No	Silica fumes	Avg. compressive strength (MPa)	
		7 Days	28 Days
1	0%	49.53	70.26
2	5%	50.35	71.32
3	7.50%	51.28	72.86
4	10%	50.93	71.97

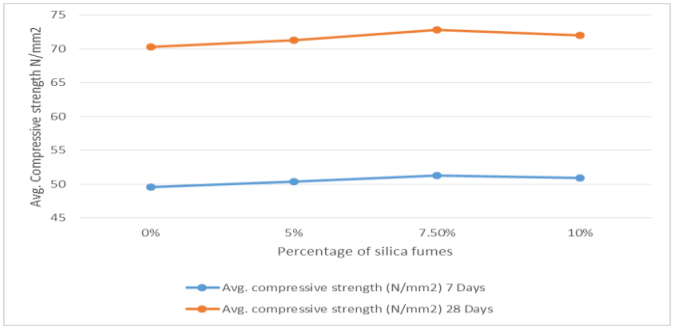

Fig -1: Variation in compressive strength for different proportions of silica fumes

Table-3 shows 7 & 28 days compressive strength of M60 grade concrete for different percentage of steel fibers. Figure-2 shows the variation in compressive strength of M60 grade concrete with percentage of steel fibers-

Table.3: Determination of optimum dose of steel fibers

S.No.	Steel Fibers	Avg. compressive strength (MPa)	
		7 Days	28 Days
1	0%	49.53	70.26
2	0.50%	52.55	73.36
3	1%	54.42	78.92
4	1.50%	45.93	75.58

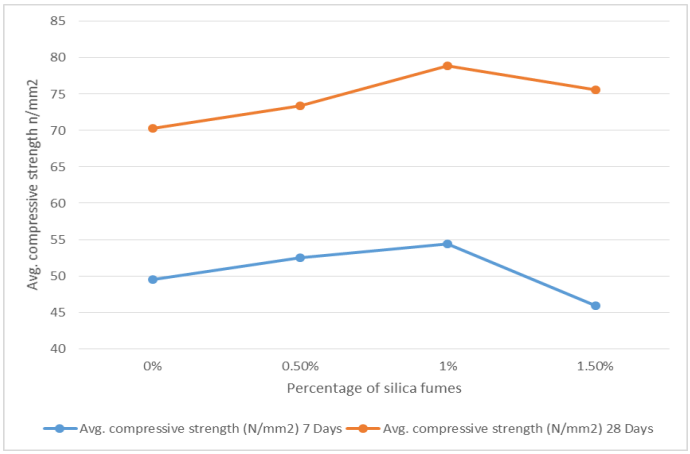

Fig. 2: Variation in compressive strength for different proportions of steel fibers

From the above tables & curves we can conclude that the optimum quantity silica fume is 7.5% and steel fibers is 1%. These optimum dose of silica fumes & steel fibers is added to do the further study on effect of wheat straw ash can use in further experimental study.

After determining the optimum dose of silica fume and steel fibers, further study was conducted on replacing the cement with wheat straw ash. The percentage of wheat straw ash used was 5%, 10% & 15% with the designed concrete of M60, M70 & M80 cylinders and beams were prepared and tested.

Split Tensile strength Test:-

The Split Tensile Tests were performed on concrete cylinder of size 150mm Dia. And 300mm height as per IS (IS 5186 (1999)) by adding steel fibres (1%) and replacing cement with Silica fume (7.5%) and different proportions of wheat straw ash. The wheat straw ash replacement percentages were 5%, 10%, 15% by weight of cement. For each replacement level six cylinder were cast and cured. These number of number of cylinder were tested after 7 days of curing while remaining three cylinder were tested after 28 days of using. Final strength was taken by the average value of three specimens.

Table.4: Avg. split tensile strength at 7 days

S.No.	Steel Fibres	Silica fumes	Wheat Straw Ash	Avg. split tensile strength at 7 days (MPa)		
				M60	M70	M80
1	0%	0%	0%(Plain)	2.47	2.58	2.92
2	1%	7.50%	0%	2.52	2.66	3.16
3	1%	7.50%	5%	2.67	2.86	3.23
4	1%	7.50%	10%	2.51	2.71	3.07
5	1%	7.50%	15%	2.44	2.54	2.88

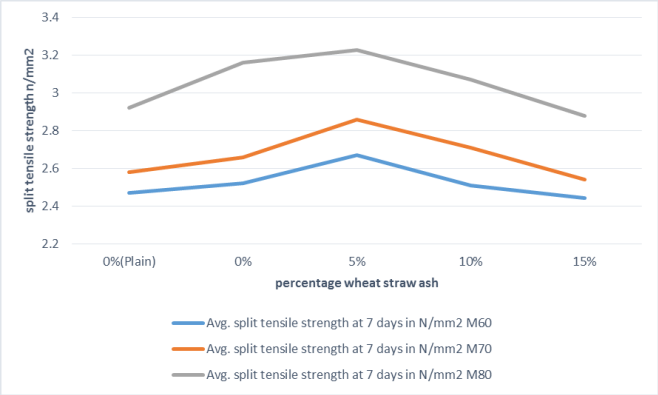

Fig. 3: Variation of split tensile strength (7 days in N/mm2) with different percentage of wheat straw ash

Table-4 shows the results of split tensile strength for different grades of concrete for different percentage of wheat straw ash. Fig. 3 shows variation in split tensile strength of different grades of concrete against the percentage of wheat straw ash at 7 Days.

Table.5: Avg. split tensile strength at 28 days

S.No.	Steel Fibres	Silica fumes	Wheat Straw Ash	Avg. split tensile strength at 28 days (MPa)		
				M60	M70	M80
1	0%	0%	0%(Plain)	3.47	3.89	4.12
2	1%	7.50%	0%	3.72	3.92	4.66
3	1%	7.50%	5%	3.86	4.21	4.81
4	1%	7.50%	10%	3.54	4.09	4.21
5	1%	7.50%	15%	3.39	3.87	3.92

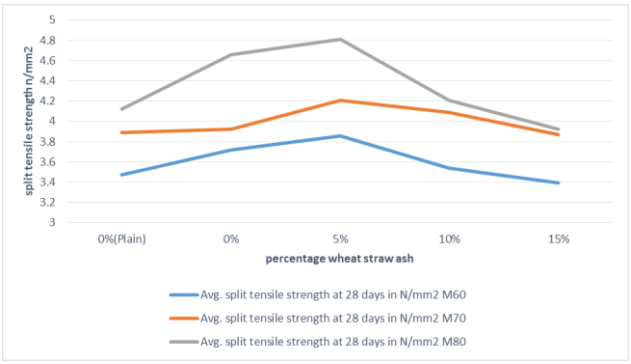

Fig. 4: Variation of split tensile strength (28 days in N/mm2) with different percentage of wheat straw ash

Table-5 shows the results of split tensile strength for different grades of concrete for different percentage of wheat straw ash. Fig. 4 shows variation in split tensile strength of different grades of concrete against the percentage of wheat straw ash at 28 Days.

Flexural strength Test:

The flexural strength Test was performed on concrete beam of size 100mmX100mmX500mm as per IS (IS 516-1959) by adding steel fibres (1%) and replacing cement with Silica fume (7.5%) with different percentage of wheat straw ash. The wheat straw ash replacement percentages were 5%, 10%, 15% by weight of cement. For each replacement level six beams were cast and cured. Three beams were tested at the age of 7 while the remaining were tested after 28 days of curing. Final strength was taken by the average value of three specimens.

Table.6: Avg. flexural strength at 7 days

S.No.	Steel Fibres	Silica fumes	Wheat Straw Ash	Avg. flexural strength at 7 days (MPa)		
				M60	M70	M80
1	0%	0%	0%(Plain)	5.57	5.89	6.37
2	1%	7.50%	0%	5.73	6.13	6.39
3	1%	7.50%	5%	5.93	6.37	6.52
4	1%	7.50%	10%	5.65	5.91	6.44
5	1%	7.50%	15%	5.41	5.88	6.11

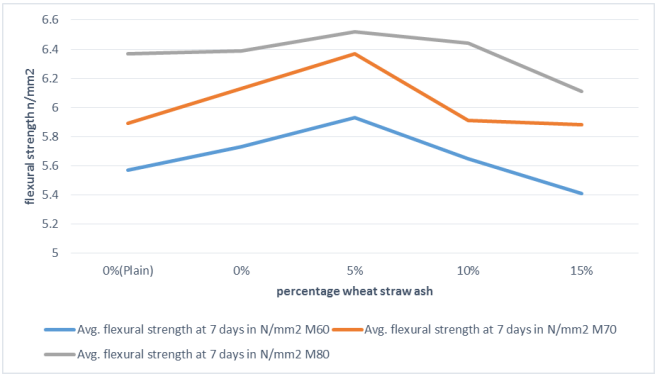

Fig. 5: Variation of flexural strength (7 days in N/mm2) with different percentage of wheat straw ash

Table-6 shows the results of flexural strength for different grades of concrete for different percentage of wheat straw ash. Fig. 5 shows variation in flexural strength of different grades of concrete against the percentage of wheat straw ash at 7 Days.

Table.7: Avg. flexural strength at 28 days

S.No.	Steel Fibres	Silica fumes	Wheat Straw Ash	Avg. flexural strength at 28 days (MPa)		
				M60	M70	M80
1	0%	0%	0%(Plain)	828	8.57	9.32
2	1%	7.50%	0%	8.44	8.87	9.4
3	1%	7.50%	5%	8.65	9.21	9.52
4	1%	7.50%	10%	8.54	9.13	9.48
5	1%	7.50%	15%	8.42	8.92	9.32

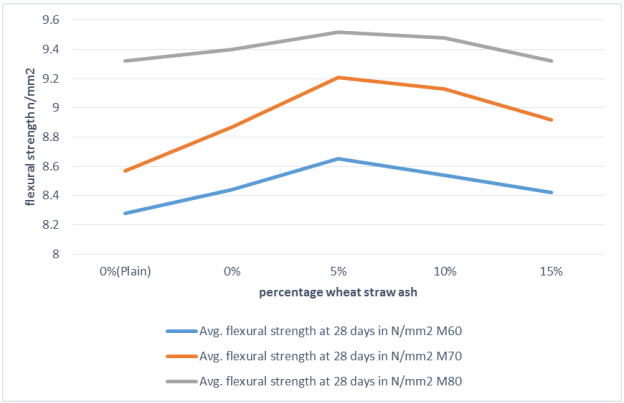

Fig. 6: Variation of flexural strength (28 days in N/mm2) with different percentage of wheat straw ash

Table-7 shows the results of flexural strength for different grades of concrete for different percentage of wheat straw ash. Fig. 6 shows variation in flexural strength of different grades of concrete against the percentage of wheat straw ash at 28 Days.

Cost Analysis: cost analysis is done by comparing cost of conventional concrete and concrete with different additives. The Cost Analysis of concrete is done as per the market rates and schedule of Rates by Central Public Works Department, 2021.

Table.8: Cost estimate of Normal Concrete for M60 grade concrete

S. No.	Particular	Quantity	Units	Rate (Rs)	Amount
1	Cement	9.3	bag	330	3069
2	Fine Aggregates	0.709	Cubic meter	900	635.4
3	Coarse Aggregates	1.312	Cubic meter	1400	1836.8
Total					5541.2

Table.9: Cost estimate of Concrete for M60 grade using Wheat straw ash, silica fumes & Steel Fibers

S. No.	Particular	Quantity	Units	Rate (Rs)	Amount
1	Cement	7.2076	bag	330	2378.51
2	Fine Aggregates	0.709	Cubic meter	900	635.4
3	Coarse Aggregates	1.312	Cubic meter	1400	1836.8
4	Silica Fume	34.87	Kg	5	174.35
5	Wheat Straw Ash	69.75	Kg	0	0
6	Steel Fibers	4.65	Kg	50	232.5
7	Net Cost				5257.56

Table.10: Cost Analysis for M60 grade concrete

1	Cost of Normal Concrete	5541.2
2	Cost of concrete using silica fume, wheat straw ash and steel fibers	5257.56
3	Percentage in cost of saving per m^3 of concrete	5.39%

Similarly, we have performed the cost analysis for M70 & M80 grade concrete and we concluded that-

- Percentage saving per m3 of concrete for M70 was 4.98%.
- Percentage saving per m3 of concrete for M80 was 5.63%.

From above cost analysis we found that replacement of cement with wheat straw ash, silica fume and steel fibers can be economical & environmental friendly for mass concrete work.

6. CONCLUSIONS

Following are the conclusions-

- The optimum percentage of silica fume and steel fiber for the design of different high grade concrete is found to be 7.5% and 1% respectively.
- Although at 5% replacement of cement with wheat straw ash, maximum split tensile and flexural strength is obtained, but even at 15% replacement of cement with wheat straw ash the achieved strengths are more than the targeted strength. Hence to achieve maximum economy, it is recommended to use 15% wheat straw ash.
- Apart from economical point of view, it is observed that, replacement of cement with wheat straw ash, silica fume and steel fibers can be economical & environmental friendly for mass concrete work. It will not only reduce the consumption of cement, which will be ecofriendly but will also solve the problems of disposal of wheat straw ash.

REFERENCES

[1] Al-Akhras N.M., Abu-Alfoul B.A. (2002) "Effect of wheat straw ash on mechanical properties of autoclaved mortar" – journal of Cement and Concrete Research 32 (2002) 859–86.

[2] Perumal, K., Sundararajan , R. (2004) "Effect of partial replacement of cement with silica fume on the strength and durability characteristics of High performance concrete" - 29th Conference on OUR WORLD IN CONCRETE & STRUCTURES: 25 - 26 August 2004, Singapore.

[3] Santhi A.S., et al. (2011) "Study on Strength Development of High Strength Concrete Containing Fly ash and Silica fume" - International Journal of Engineering Science and Technology 2011.

[4] Roy, D. K. (2012) "Effect of Partial Replacement of Cement by Silica Fume on Hardened Concrete" - International Journal of Emerging Technology and Advanced Engineering, 2(8), 472-475.

[5] Sabale V. D., et al. (2014) "Study the Effect of Addition of Silica Fume on Properties of High Strength Concrete" - International Journal of Engineering Research & Technology Volume 3 issue 1, 2014.

[6] Choudhary S., et al. (2014) "Study Of High Performance Concrete" - Journal of Civil Engineering and Environmental Technology Volume 1, 2014.

[7] Qiang Z., et al. (2014) "Effect of rape straw ash and silica fume admixture on concrete performance" - Journal of Hunan Agricultural University (Natural Sciences), 2014, 40(3): 334-336.

[8] Pandit R.D. & Wadekar A.P. (2015) "Study of High Strength Fibre Reinforced Concrete by using Two Types of Fibres" - IJREST 2015.

[9] Kumar A., et al. (2015) "Partial Replacement of Cement in M-30 Concrete from Silica Fume and Fly Ash" - SSRG International Journal of Civil Engineering, 3(5), 40-45, 2015.

[10] Hamiruddin N.A., et al. (2018) "Effect of steel fibre content with high strength fibre reinforced concrete on compressive behavior" - AIP Conference Proceedings 2030, 020049 (2018).

[11] Zheng Y., et al. (2018) "Mechanical Properties of Steel Fiber-Reinforced Concrete by Vibratory Mixing Technology" - Advances in Civil Engineering Volume 2018.

[12] Hamiruddin N.A., et al. (2018) "Effect of Steel Fibre Contents with High Strength Fibre Reinforced Concrete" - International Journal of Advances in Scientific

Research and Engineering (Volume 4, Issue 3 March – 2018).

[13] Shar I.A., et al. (2019) "Use of Wheat Straw Ash as Cement Replacement Material in the Concrete" - International Conference on Sustainable Development in Civil Engineering 2019.

[14] Khan M.S., et al. (2019) "A Study of Properties of Wheat Straw Ash as a Partial Cement Replacement in the Production of Green Concrete" - UW Journal of Science and Technology Vol. 3 (2019) 61-68.

[15] Yanxia Ye, et al. (2020) "Experimental Study of High-Strength Steel Fiber Lightweight Aggregate Concrete on Mechanical Properties and Toughness Index" - Advances in Materials Science and Engineering Volume 2020, Article ID 5915034.