New Alternative Recycled Cloth Fiber Based on Cement

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Abstract

This study explores the potential of using recycled cloth fibers from fabric recycling plants and tests the properties of cement mixed with recycled cloth fibers. The composite composed cement, water, and 3 different lengths of recycled textile fiber (short, medium and long fiber). The composition ratio of cement to water to fiber is as follows: 1:1:0.10, 1:1:0.25 and 1:1:0.50 by weight. The physical, mechanical, and thermal properties were measured according to test standards and compared to conventional building materials.

The results found that different cloth fibers based-on cement have the potential to be used in the production of a new alternative material. Using recycled cloth fiber as an ingredient in cement will help reduce the bulk density and thermal conductivity value. The short cloth fiber in the composite results in high density, and compressive strength. Water absorption is low but thermal conductivity is high. When comparing the test properties of the specimens with the standard material, it was found that the specimens with ratios of 1:1:0.10 and 1:1:0.25 passed the non-load bearing wall material and had better properties than the conventional wall blocks in the local market.

Moreover, it can be applied as a sustainable lightweight insulating material for both wall spraying and 3D printing.

Keywords:
recycled cloths, recycling, lightweight composite, building materials

1. Introduction

Recycling is one of the best practices for the efficient use of resources and there are many old or damaged textile and clothing material each year. Some textiles are collected, spun and recycled into fibers at a fabric recycling plant (Figure 1).

These fibers are then sold to be used as secondary and support materials such as mattresses and furniture, etc. From this fabric recycling process, there will be a lot of fiber powder produced (Figure 1), on average about 200 kilogram per week per factory (from the inquiry of a fabric recycling plant in Saraburi province, Thailand). This filament powder is then discarded, used to make fuel and filled with soil. The use of recycled fabric fibers and waste fibers as a mixture of cement to make building materials and finishing materials is still being studied and applied in a small number of countries.

In Thailand, a study on the use of fibers from agricultural waste fibers as composites for building materials (Khedari et al., 2004, 2005; Asasutjarit et al., 2007; Sangrutsamee et al., 2012, 2018) etc. found that fibers help the material to have better properties as follows: less cracking, lighter weight and better heat protection, etc.

In foreign countries, there have been studies on the use of rag fibers in building materials. Wang et al. (2000) studied and offers that using recycled fibers from industrial or postconsumer waste can provide additional advantages for waste reduction and resources conservation. Fiber reinforcement in concrete can practically improve toughness, shrinkage, and durability characteristics. Sadrolodabaee et al. (2021) found that using this textile waste composite as a potential construction material in nonstructural structures such as facade cladding, raised floors, and pavements was most feasible.

The objective was to explore the potential of using recycled fiber cement in the production of alternative building materials with low thermal conductivity. The physical (density, water absorption), mechanical (compressive strength), and thermal properties of this material were studied with the different types of the recycling cloth fiber and the different ratios. Its properties of the samples were compared to the values of commercial materials available in the local market.

a) remnants b) recycled fabric fibers c) filament powder (Waste from the recycling process)

Figure 1 Image of cloth rags, recycled fabric fibers and filament powder

2. Materials and experiment methodology

2.1 Raw materials

The raw materials used are as follows:

(i) Portland cement: An ordinary Portland cement made by the Thai Petrochemical Industry (TPI) brand, Type I which complies with ASTM C 150-89.

(ii) Mixing water: The main water supply of the province was used.

(iii) Recycled cloth fibers: the three difference lengths are the following

I. The short fiber: fiber length less than 5 mm. This filament powder was left over from the waste recycling plant.

II. The medium fiber: fiber length in the range of 6-10 mm. which was spun into fibers from a rag recycling plant.

III. The long fiber: fiber length more than 11 mm. which was also spun into fibers from a rag recycling plant.

The physical characteristics of the three different types of the recycled cloths are shown in Figure 2.

2.2 Specimen preparation

This experiment investigated the physical, mechanical and thermal properties of the fiber-based on cement composite on the different types of recycling cloth fiber and the different composite ratios.

The procedure for preparing the test specimens and the mix ratio was done as follows:

1) Preparing and weighing the recycled cloth fibers, Portland cement and water in a container according to the desired ratio following Table 1.

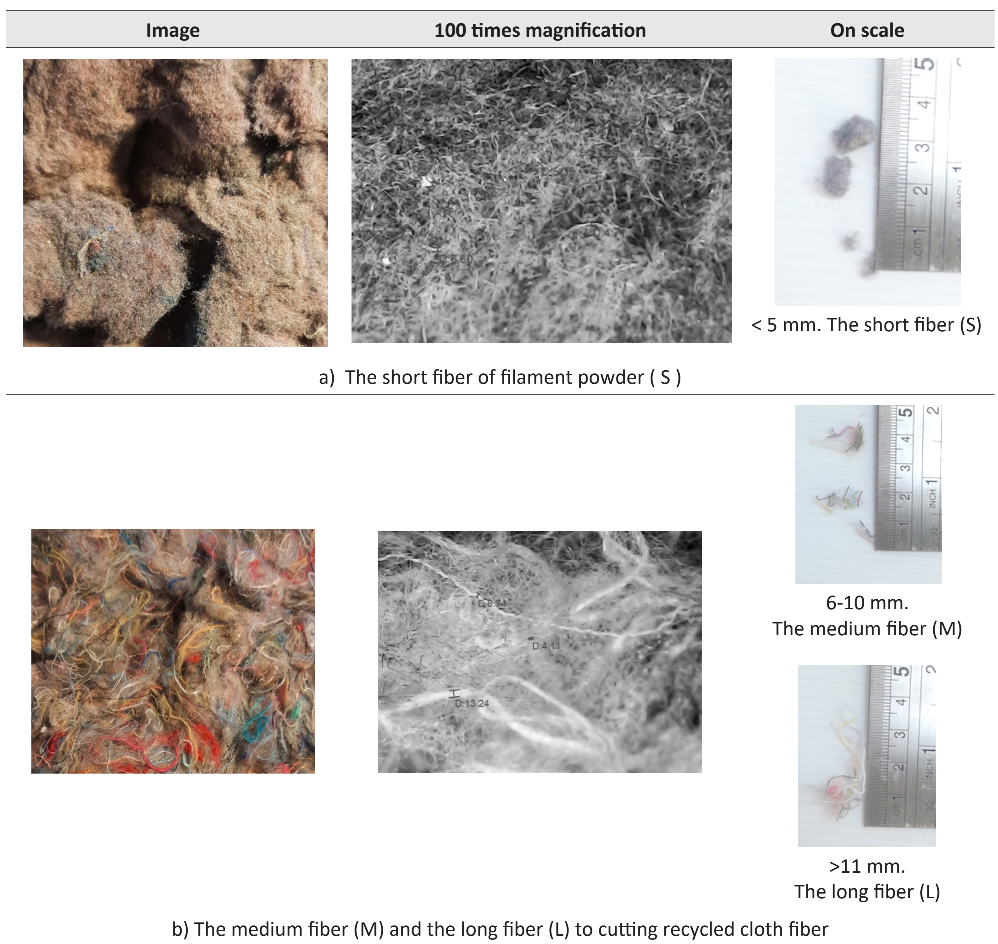


Figure 2 The three difference types of the tested cloth fiber on scale

Lengths of recycled cloth fiber	Symbol	Fiber content to cement by weight (Percentage)	Weight ratio mixture (gram)		
			Cement	Water	Cloth fiber
S (Short) <5 mm. (Filament powder)	S10	10%	1	1	0.10
	S25	25%	1	1	0.25
	S50	50%	1	1	0.50
M (Medium) 6-10 mm.	M10	10%	1	1	0.10
	M25	25%	1	1	0.25
	M50	50%	1	1	0.50
L (Long) >11 mm.	L10	10%	1	1	0.10
	L25	25%	1	1	0.25
	L50	50%	1	1	0.50

Table 1 Mix details of the composite specimens

a) Mixture b) Dimension c) Compressive strength test d) The samples after testing

Figure 3 Mixture preparation and material testing

2) Start by mixing the fibers together with the cement. Then pour in water in the ratio of 1 to 1 weight of the cement. Considering the water content in all the mixtures, the admixtures are quite liquid (See Table 1 and Figure 3a). Because this fiber absorbs a lot of water. Mixing this mixture will be easy and convenient to pour or spray in forming.

3) Mix all the materials together with an electric blender (Figure 3a) for about 3 minutes.

4) Pour the resulting mixture into the prepared mold. Then prod the material to spread it evenly across the mold and smooth the top of the surface.

5) Curing the workpiece for 3 hours, then remove the mold. Three specimens per ratio are made and resulted in 27 specimens in total.

6) Bring the specimens to be incubated at a room temperature area for 28 days, after which they are tested.

The amount of fiber in the mixture seems to be low by weight, but effective by volume. The fiber content is about 3 times the volume of cement. Because the fiber density is much lower than that of cement.

2.2 Test methods

Three replicate samples were prepared for testing resulting in 27 specimens. The composite specimens were tested based on the following testing standards:

- Physical properties (dimension, shape, bulk density and water absorption): Performed according to ASTM C 134-88. Shaped specimens were dried at laboratory conditions (24°C, 56% relative humidity (RH)) and then dried to a constant weight at 105 °C in the oven (Figure 3b).

- Mechanical properties (compressive strength): Measured according to ASTM C 109/C 109-95. Before testing, the 50-mm-side cube specimens must be incubated at room temperature for 28 days (Figure 3c and Figure 3d).

- Thermal properties (thermal conductivity): Tested according to JIS 2618 at 40°C for thermal conductivity with temperature at 24°C, RH 56%.

3. Result and discussion

The results of all test specimen properties are shown in Table 2.

Table 2 Average measured properties of the three specimens

Specimen	Fiber content to cement by weight (Percentage)	Thermal conductivity (W/m-K)	Bulk density (kg/m³)	Compressive strength (MPa)	Water absorption (%)
S10	10%	0.229	1593.67	3.44	9.54
S25	25%	0.193	1397.98	2.93	14.46
S50	50%	0.158	1021.10	1.99	19.14
M10	10%	0.222	1557.60	3.43	10.66
M25	25%	0.170	1386.43	2.67	14.59
M50	50%	0.144	1010.61	1.94	19.70
L10	10%	0.196	1553.45	3.29	10.86
L25	25%	0.166	1349.83	2.56	15.22
L50	50%	0.140	1009.20	1.84	19.96

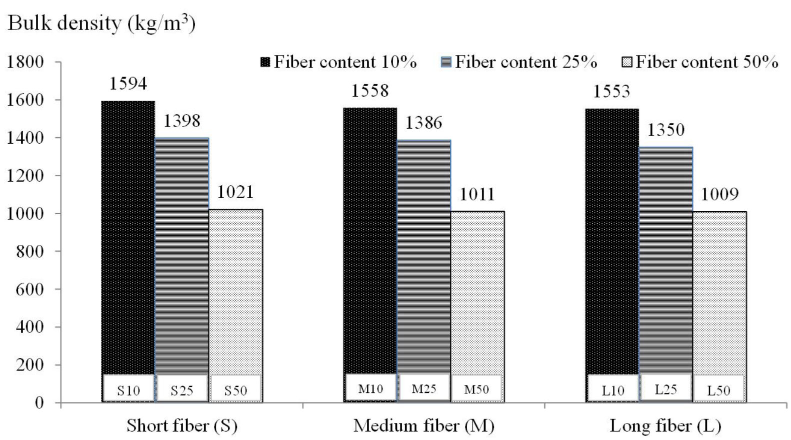


Figure 4 Effect of different fiber lengths and mixed proportions on bulk density

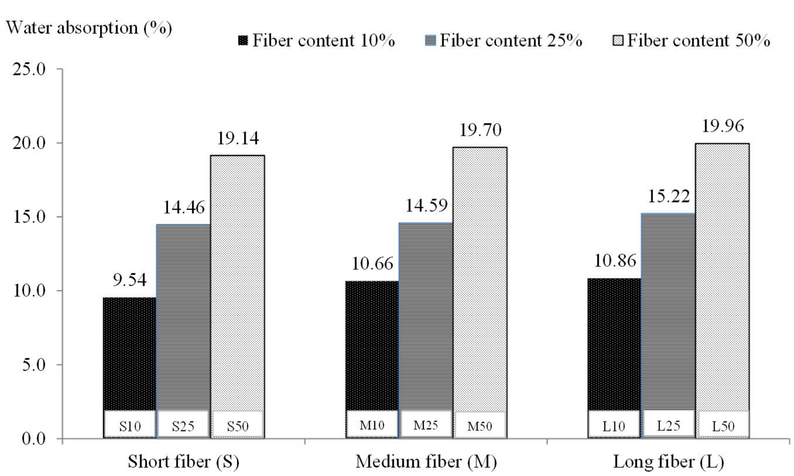


Figure 5 Effect of different fiber lengths and mixed proportions on water absorption

3.1 Bulk density

The density of the specimens is shown in Figure 4. Comparing the fiber content in the mixture, the S50, M50 and L50 test specimens, that which had the highest amount of recycled cloth fiber in the mixture, had the lowest density.

In fact, physical property of cloth fibers is low density with many air voids between fibers. Therefore, when the proportion of this fiber increases, its density properties are reduced. Therefore, adding lightweight aggregate in the composite will decrease its density. Comparing different types of recycled cloth fiber, L50 test specimens using long fiber in the mixture showed the lowest density. The bulk density of the specimen decreases as the fiber length increases. It may be that using longer fibers as a composite makes it difficult to line up in any direction. This results in many small voids in the mixture.

3.2 Water absorption and bulk density

Water absorption of the specimen is shown in Figure 5. It indicated that 50% fiber content (S50, M50 and L50) in the composite had the highest water absorption. This is due to the fact that recycled fibers are characterized by high water absorption. The higher the fiber content in the mixture, the greater the water absorption value, where the binder (cement) helps adhesion to have only partially reduced water absorption. The hydrophilic fiber has high water absorption even when bonded and coated with cement.

Water absorption versus bulk density is shown in Figure 6. It was observed that water absorption value increased when bulk density decreased. So, air voids and characteristic cloth fiber in the composite can absorb water highly.

3.3 Compressive strength and bulk density

Compressive strength of the specimen is shown in Figure 7. Its show the test specimens with fiber 10% (S10, M10 and

L10) in the mixture have the best compressive strength. It shows that when the compressive strength is higher, the amount of recycled fiber decreases.

Compared with the Thai Industrial Standard for hollow non-load bearing masonry units (TIS 58-2530), the compressive strength must be at least 2.5 MPa. It was found that all specimens with 10% and 25% (S10, S25, M10, M25, L10 and L25) fibers passed this standard.

When comparing different types of recycled fiber in composite, it was found that the shorter recycled fiber composites have a slightly higher compressive strength than long fiber composites.

Figure 8 shows the compressive strength versus the bulk density. It indicates that an increase in bulk density relationship results in a higher compressive strength.
The results of this study are similar to those of Benchikou et al. (2012) showing the compressive strength varies with the material density. Increasing the fiber content of the mixture influences the increase of cavitation in the material and reduces the material's light weight and strength.

3.4 Thermal conduction and bulk density

The average thermal conductivity of the specimens is shown in Figure 9. It was found that a 50% cloths fiber content in the composite (S50, M50 and L50) had the lowest thermal conductivity. In fact, the basic properties of cloth fiber is low thermal conductivity and density when the cloth fiber content in composite increases the thermal conductivity and density of the sample decreases. Thermal conductivity versus bulk density is shown in Figure 10. It shows that the thermal conductivity value decreased when the bulk density decreased. This result is the same of Khedari J., et al. (2004). who said thermal conductivity varies proportional to the decrease of specimens' density.

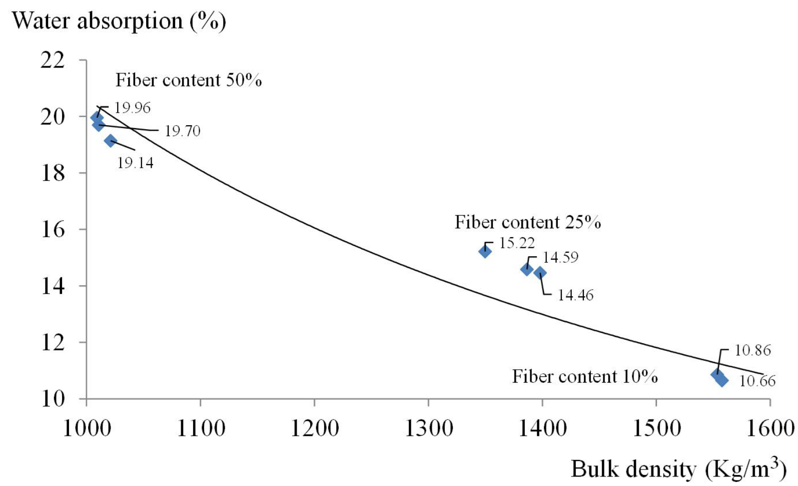


Figure 6 Relation between water absorption and bulk density

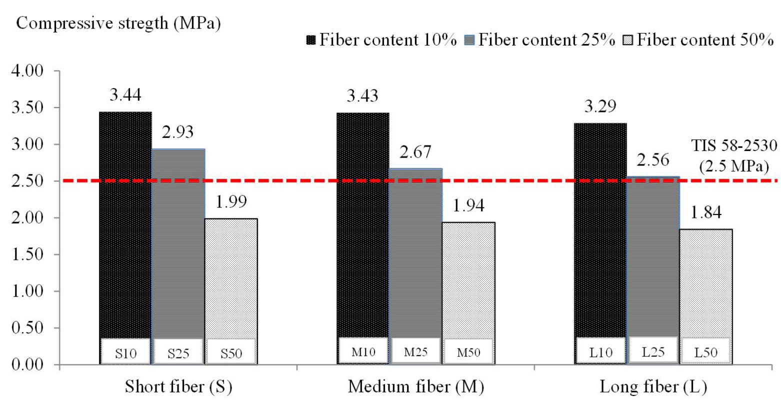


Figure 7 Effect of different fiber lengths and mixed proportions on compressive strength

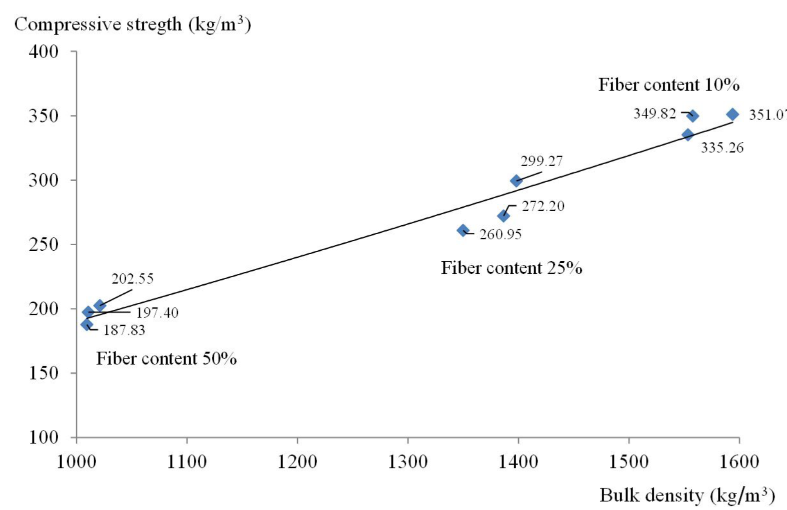


Figure 8 Relationship between compressive strength and bulk density

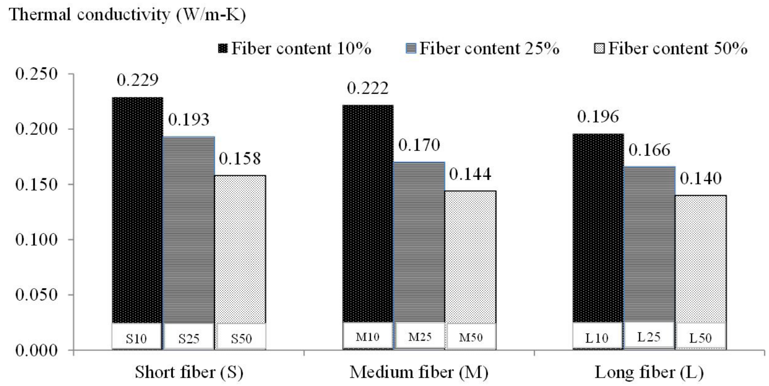


Figure 9 Effect of different fiber lengths and mixed proportions on thermal conductivity

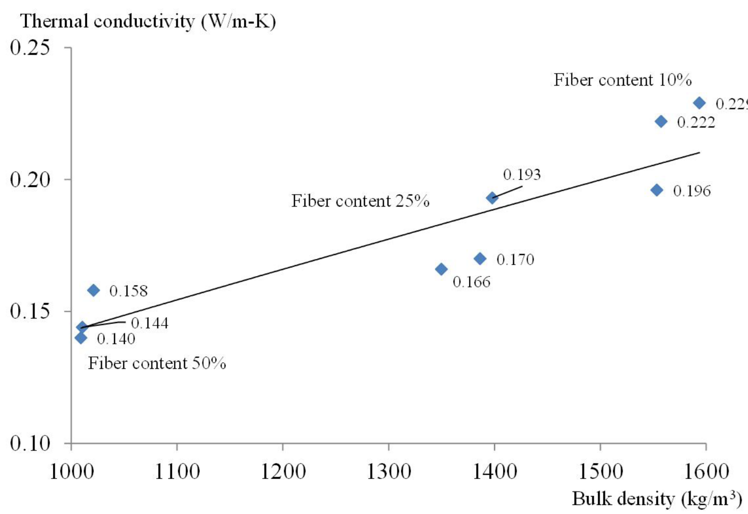
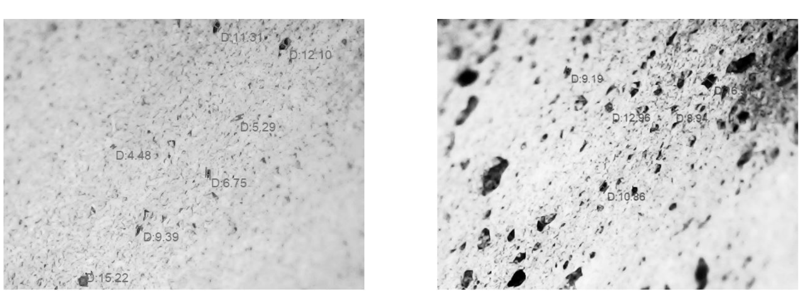


Figure 10 Relationship between thermal conductivity and bulk density



a) S25 b) S50

Figure 11 Enlarged image insidethe S25 and S50 sample (100 times)

The longer fiber in the composite has lower thermal conductivity than short fiber in the others. It may be that the long cloth fiber is difficult to arrange in the mixture, thus creating many air gaps in the material and lower thermal conductivity than short fibers in the mixture. Observing the inside of cement mixed with recycled cloth fiber, many tiny voids appear as shown in Figure 11 which affects the bulk density and thermal conductivity of the material.

3.5 Comparison to the recycled cloth fiber based on composite and commercial materials

From the results discussed in the previous sections, it can be seen that 25% cloth fiber in composite (S25) is the most suitable for both physical, mechanical and temperature properties. This short fiber is a fiber left over from the fabric recycling process.

A comparison of the properties between the optimized samples and wall block in local market is shown in Table 3. The cloth fiber based on cement have the advantage of being light in weigh and possess good thermal insulation properties.

4. Conclusion

From this study it can be concluded that the development of recycled cloth fiber based on cement is effective in the development of non-load-bearing wall block building material. It has a compressive strength, density and water absorption which are in accordance with the requirements of Thai industry standards. Moreover, it also has a lower thermal conductivity than other building materials in the market.

The use of different recycled fiber types and different content ratios can be summarized as follows:

- Using recycled cloth fiber in the composite will help have a lower density and thermal conductivity but have a lower compressive strength and increased water absorption.

- The different types of recycled cloth fibers affect the properties of the material. The shorter cloth fiber in the mixture will increase the bulk density, thermal conductivity, and compressive strength value and the water absorption value is reduced.

- The ratio of recycled fibers in cement suitable for the development of non-load-bearing wall blocks is: 1 part cement, 1 part water, and 0.25 parts by weight. Aside from being able to evolve into this wall building block, it can also be developed into wall-spray insulation materials or materials for 3D printing due to the very high water content in this mixture.

- Finally, cloth fiber in the composite is a new alternative lightweight building material which saves energy and reduces environmental problems.

Table 3 Comparison of the physical, mechanical and thermal properties of the tested composite to commercial building materials

Types of board	Density [kg/m^3]	WA [%]	Compressive strength [MPa]	Thermal conductivity [W/m-K]
Local clay brick	1569	30	3.5	1.150
Local hollow core block	972	25	2.8	0.519
S25 Specimen	1398	15	2.93	0.193
S10 Specimen	1594	10	3.44	0.229

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