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Performance of Cement Brick by Utilizing Ceramic Tiles Waste

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Abstract

Cement brick, a common construction material, contains sand as a core component. As the construction industry's demand for sand rises annually, concerns about depleting natural resources intensify. In contrast, the potential to repurpose ceramic waste, typically recycled, emerges as a viable strategy for partially substituting fine aggregates and thus could contribute to preserving sand reserves in the construction sector. This study explored the strength characteristics of cement bricks when ceramic waste is used as a partial substitute for sand. Ceramic waste was incorporated at different levels (0%, 10%, 20%, 30%, and 40%) in a 1:3 ratio, yielding 30 brick samples. These samples were subjected to density testing, water absorption testing, and compressive strength testing. The result shows that the sample with 10% achieved the best overall performance in all the tests compared to other ceramic tiles waste incorporated bricks with 26.5 N/mm^2 in compressive strength, 7.1% in water absorption and 1938 Kg/m^3 in density after curing ages of 28 days. In conclusion, the optimum percentage for the replacement of Ceramic tile waste with sand is 10%.

1.0 Introduction

Brick is a building material used in construction for structures like walls, buildings, or pavements. In Malaysia, various types of bricks are commonly used in construction, including clay bricks and cement bricks. Cement bricks are a type of manufactured building material made by mixing cement, sand, and water. The mixture is put into a mould and then hardened under certain conditions, usually heat or pressure. Once the bricks have hardened, they are taken out of the moulds and left to dry more.

In the last year, many studies have been published on the production of cement bricks using recycled materials. The impact of the water-cement ratio of sand cement brick, including recycled concrete aggregate (RCA) and crumb rubber (CR) as partial sand replacement materials, was examined in Niaz Muhammad's (2020) study. Jonny et al. (2020) have conducted a study on using ceramic waste as a partial substitute for fine aggregate in cement brick. In Muhammad Shahir's brick study, cement brick is made by substituting cockle shell waste for sand. One common practice for waste management and sustainable building is to use waste materials instead of sand while making cement bricks. Choosing waste materials that preserve the bricks' strength, resilience, and other physical characteristics is crucial.

1.1 Problem Statement

The ceramic tile industry inherently generates a substantial quantity of waste. Fragile ceramic tiles are prone to breakage during production or transportation, and the subtractive techniques employed in their fabrication result in significant waste material. China, the leading global producer of ceramic tiles, manufactured over 8.5 billion square meters of tiles in 2020. The Indian ceramic sector is a prominent player on the global stage, with an estimated value of $3.72 billion. It manufactures approximately 55 million ceramic tiles each year. However, a daily waste of around 8% to 10% of the material occurs throughout the process of making ceramic tiles. This is an inevitable consequence of the existing production processes, as the fragile tiles are prone to breaking during both the manufacturing process and transportation. Currently, the ceramics industry is facing the challenge of identifying effective methods to recycle this waste instead of just disposing of it in landfills and wasting the energy and carbon resources invested in tile production. (Ben Pilkington., 2021).

In recent years, there have been a lot of active projects in different parts of the world that will use a lot of cement and sand. The proportion of sand and cement may result in cost savings since the primary material is already inside CTW. However, it is essential to research the appropriate amount of CTW that can be used to substitute natural sand in such bricks without degrading their original performance and strength.

1.2 Properties of Ceramic Tiles Waste

The feature of the material from which the waste is collected mainly determines the physical qualities of ceramic tile waste. Sand has a specific gravity of 2.65 to 2.67, while CTW has a specific gravity that ranges from 2.2 to 2.6. Several data regarding the specific gravities of CTW and sand are presented in Table 1.

Table 1 *Specific gravity of CTW and Sand*

Sources	Megesh & Jayagopal (2018)	Chand (2017)	Shruthi (2016)
Ceramic Tiles Waste	2.24	2.6	2.22
Sand	2.64	2.59	2.65

1.3 Aim & Objectives

The objectives of this study are to determine compressive strength, water absorption rate, and density and to identify the optimum percentage of ceramic tile waste as a replacement for sand.

2.0 Materials & Methods

2.1 Materials

Sand, water, and Portland cement are the components used to manufacture cement bricks. In this study, the sand component of cement brick manufacture was replaced by ceramic waste. This waste ceramic was gathered from Penang's ceramic manufacturing sector, as shown in Figure 1.

Fig. 1 *Ceramic Tiles Waste*

2.2 Methods

This study made use of a cement-to-sand weight ratio of 1:3. Bricks were made with sand replacements made up of 10%, 20%, 30% and 40% of ceramic tile waste. According to BS 5628-3-2005, the brick with a standard size of 215 mm (length) x 103 mm (width) x 65 mm (depth) and various cement and sand ratios of 1:3 has been designed for brick manufacturing. The results of the brick mix ratio calculation are displayed in Table 2.

Several tests were conducted as part of this investigation, which include compressive strength test, water absorption test, and density test. All of this is done to assess CTW's benefits for sand-cement brick after curing at the ages of 7 days and 28 days.

Table 2 *Mix Ratio*

CTW	Cement (Kg)	Sand (Kg)	Water (Kg)	CTW (Kg)
CTW0	3.24	13.98	1.94	0
CTW10	3.24	12.58	1.94	1.40
CTW20	3.24	11.18	1.94	2.80
CTW30	3.24	9.91	1.94	4.07
CTW40	3.24	8.39	1.94	5.59

3.0 Result and Discussion

3.1 Compressive Strength

The compressive strength of brick with 10% CTW after 7 and 28 days of curing is shown in Figure 2, which is marginally higher than that of the control sample. Brick's minimum required compressive strength is between 7 and 7.5 N/mm2, which CTW 10% astonishingly exceeded with up to 379% after 7 days of curing and 399% after 28 days. In this testing, the CTW 10% sample's compressive strength performance was at its peak. For both 7 and 28 days of curing age, samples with CTW 20%, 30%, and 40% had significantly reduced compressive strength compared to the control sample.

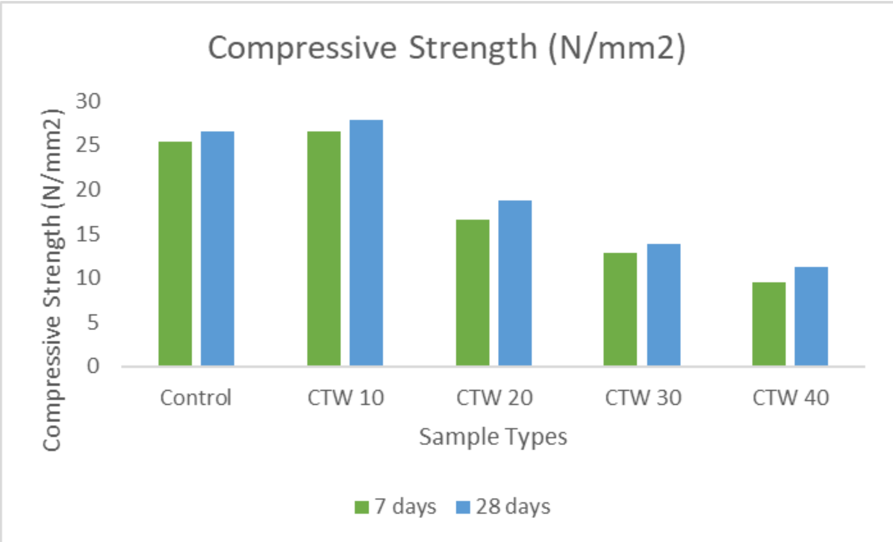

Fig. 2 *Compressive Strength of Bricks*

3.2 Water Absorption

The sample with 10% CTW on the 7-day curing age has lower average water absorption than the control sample, while on the 28-day curing age, there are only minuscule differences. 10% CTW sample for both curing ages is below the limit of water absorption for cement brick, which is 12% according to ASTM C90. CTW 10% sample has the lowest water absorption and highest strength and reached optimal performance. Other samples with 20%, 30%, and 40% CTW have higher water absorption than the control sample for both 7 days and 28 days curing age.

In summary, the percentage of CTW replacing sand leads to an increase in water absorption. Figure 3 illustrates how water absorption gradually rises as CTW percentages rise.

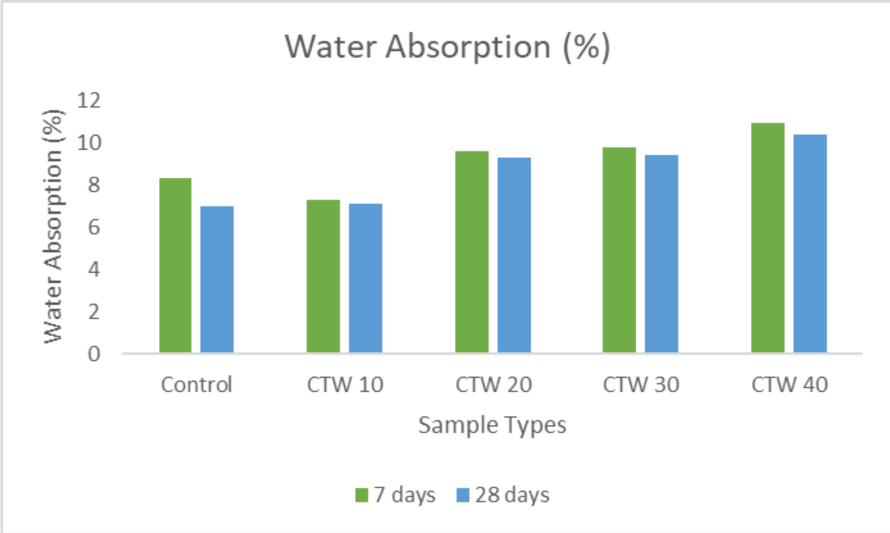

Fig. 3 *Water Absorption of Bricks*

3.3 Density

Based on Figure 4, the overall density of the control sample is higher than all other samples with percentages of CTW. The sample with 10% CTW has a higher density on 7 days of curing compared to the control sample, while the density is lower on the 28 days of curing age but has the highest density compared to other percentages samples. Due to the higher density of the CTW 10% sample, the water absorption was lowered compared to other CTW samples, and the compressive strength was drastically higher than that of other CTW samples. While other samples with 20% CTW, 30% CTW, and 40% CTW have significantly lower density compared to the control and CTW 10% samples.

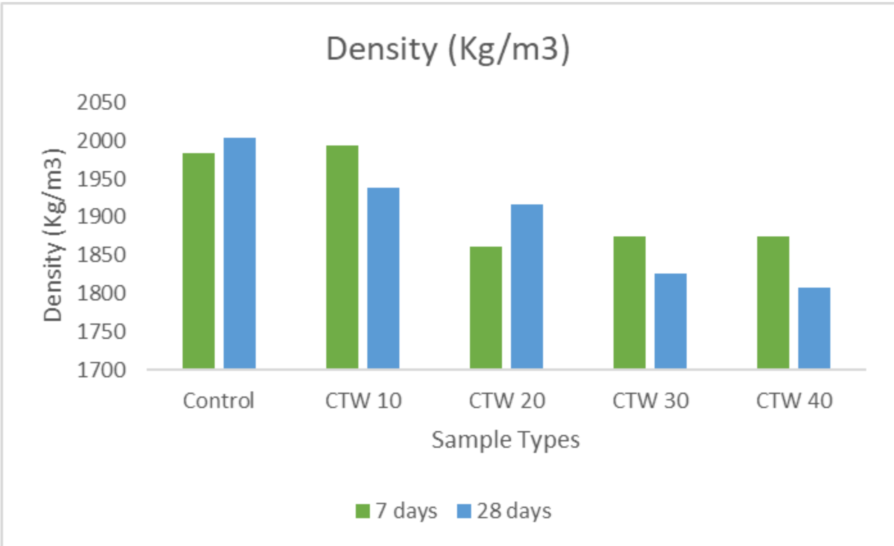

Fig. 4 *Density of Bricks*

3.4 The Relationships between the Compressive Strength, Water Absorption and Density

The link between the test findings from all three tests performed on the brick sample with the percentage of ceramic tile waste and the control brick sample was discovered to depend on the proportion of ceramic waste mixed in with the brick sample's contents.

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3.4.1 The Relationship between Compressive Strength and Water Absorption

From Figures 5 and 6, the lower the water absorption, the higher the compressive strength of the brick. Both the control and 10% CTW samples have the lowest water absorption, and the result shows that each sample has higher compressive strength.

Samples with higher water absorption, 20% CTW, 30%, and 40% CTW, resulted in lower compressive strength. This is due to the compressive strength of brick in wet conditions being lower than that in dry brick.

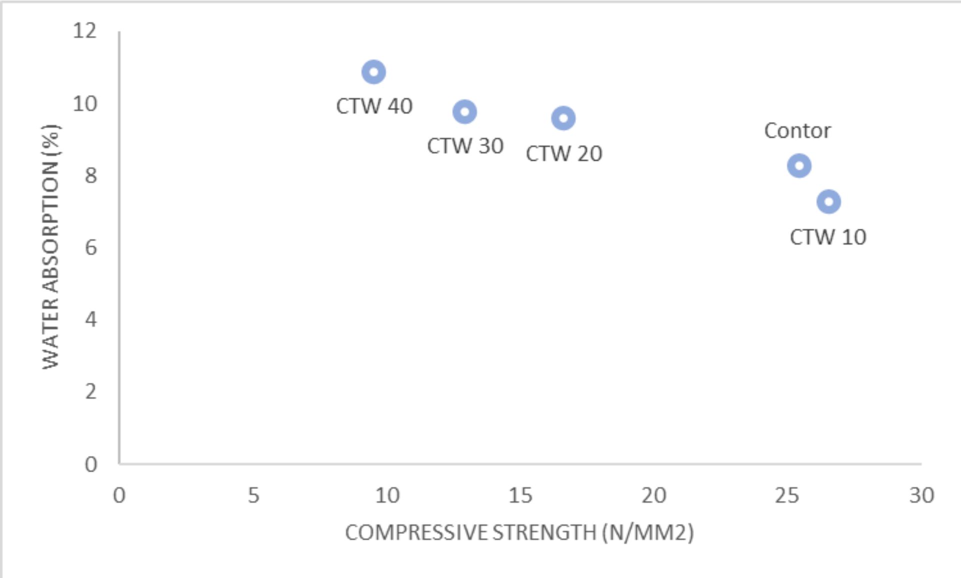

Fig. 5 *Relationship between compressive strength and water absorption for 7 days*

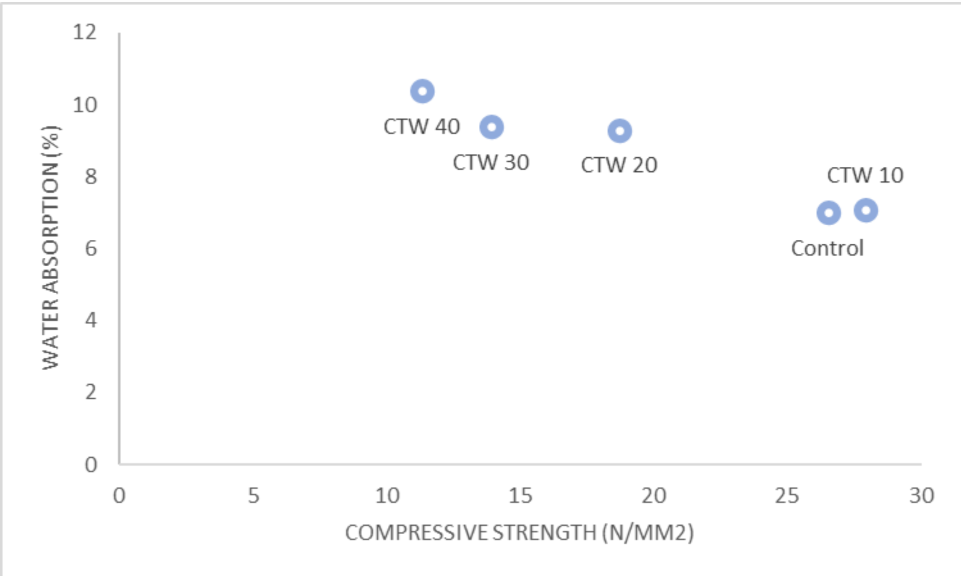

Fig. 6 *Relationship between compressive strength and water absorption for 28 days*

3.4.2 The Relationship between Compressive Strength and Density

Figures 7 and 8 show that a higher density of the brick equals higher compression brick. It can be seen that both the control sample and the 10% CTW sample have higher density, and both of these samples have higher compression strength.

The samples with a lower density, 20% CTW, 30% CTW, and 40% CTW, have lower compressive strength. This is due to the compressive strength of brick with low density being lower than that with high brick.

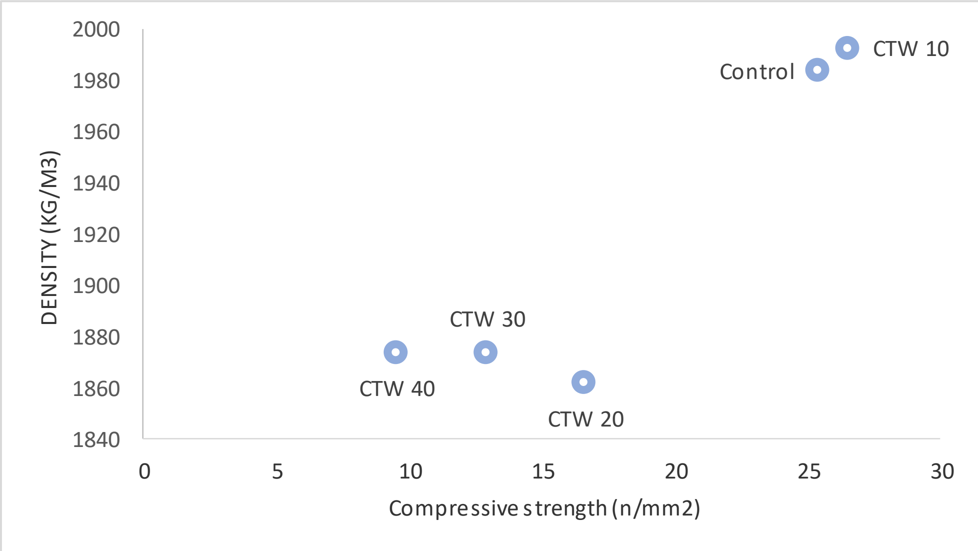

Fig. 7 *Relationship between compressive strength and density for 7 days*

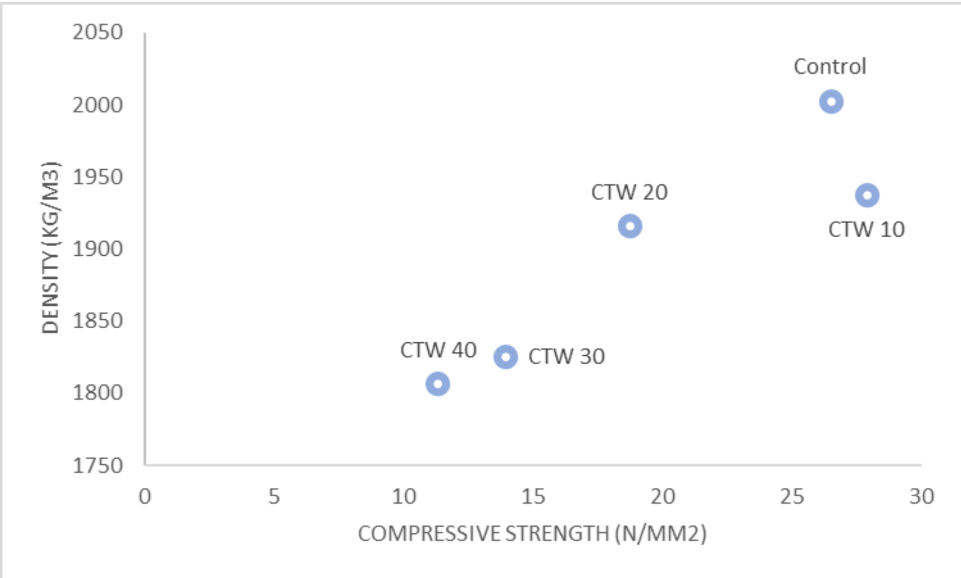

Fig. 8 *Relationship between compressive strength and density for 28 days*

3.4.3 The Relationship between Water Absorption and Density

Based on Figures 9 and 10, a brick's water absorption decreases with increasing density. Brick water absorption is lower in the 10% CTW and sample control groups, which have higher densities.

The bricks in the lower-density samples (20%, 30%, and 40% CTW) exhibit a high water absorption rate. This is because low-density brick has more pores, which enable water to seep into the brick.

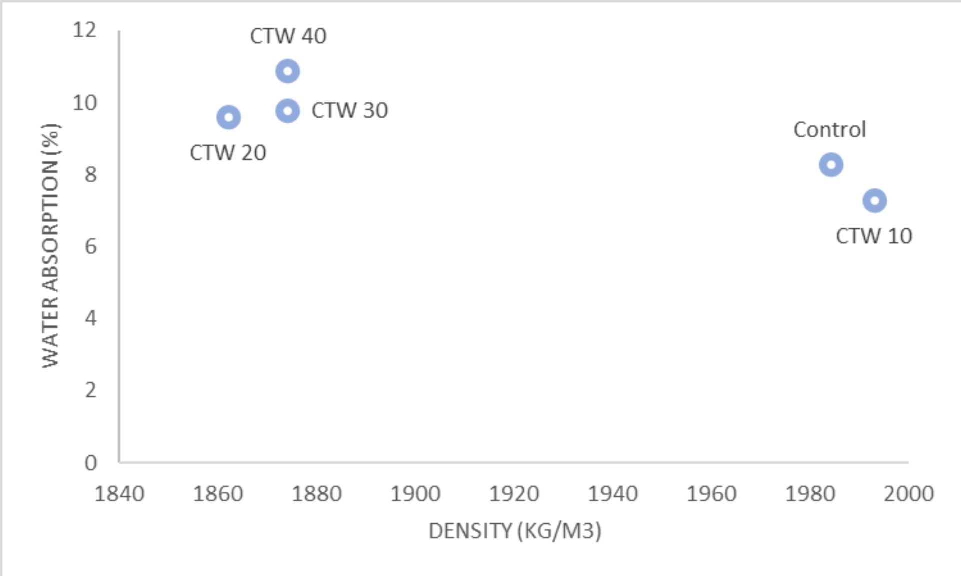

Fig. 9 *The Relationship between water absorption and density for 7 days*

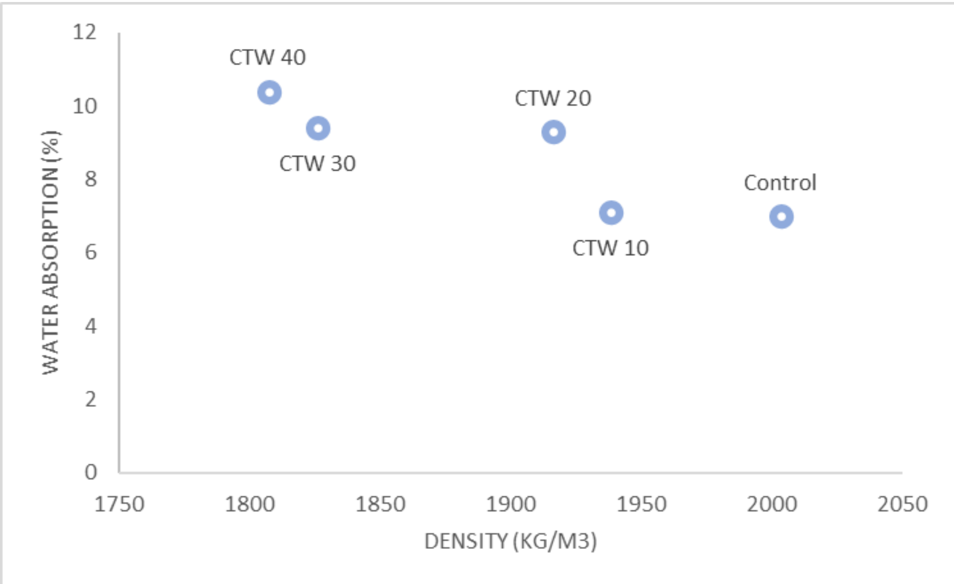

Fig. 10 *The Relationship between water absorption and density for 28 days*

4.0 Conclusion

As a result of the high compressive strength, density and low water absorption, the optimum percentage of ceramic tile waste replacement for sand is 10%. In the realm of construction innovation, the 10% CTW sample reached the optimal performance. All other samples also achieve the minimum requirement of 7 N/mm^2 in compressive strength and water absorption lower than 12% but have major differences in terms of the strength of the control.

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