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Sustainable Reuse of Formula Milk Tin Waste for Enhancing Concrete Confinement

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Abstract: Concrete columns play a vital role in structural systems due to their ability to resist axial and lateral loads. Enhancing column performance through confinement has been widely studied, particularly using steel tube confined concrete (STCC). In parallel, the growing amount of metal waste highlights the need for innovative and sustainable reuse strategies. One type of waste with a geometry similar to steel tubes is formula milk tins, which are commonly discarded household products. This study investigates the potential use of formula milk tin waste as external confinement for concrete specimens. Concrete cylinders confined with formula milk tins (13 cm in diameter and 16 cm in height) were compared with standard cylindrical specimens (15 cm × 30 cm). Two types of confinement were examined: plain tins and corrugated tins. All specimens were prepared using K200-grade concrete and subjected to two curing methods, namely water curing and air curing, for 28 days. Compressive strength tests were conducted in accordance with relevant standards, and correction factors were applied to account for non-standard specimen dimensions. The results show that specimens confined with formula milk tins exhibited higher compressive strength than unconfined specimens. Corrugated tin confinement provided the greatest strength enhancement, improved stiffness, and more controlled failure behavior. While water curing resulted in higher compressive strength than air curing, the confinement effect was found to be more influential than the curing method. These findings demonstrate that formula milk tins have significant potential as an alternative external confinement material for simple concrete columns, offering both structural performance improvement and a sustainable solution for reducing metal waste.

Keywords: Concrete confinement, Formula milk tin waste, corrugated tin, sustainable construction materials, compressive strength.

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1. Introduction

Concrete is a construction material known for its high compressive strength, making it widely used in various structural applications, including columns. Concrete columns play a crucial role in structural systems as they bear axial and lateral loads, requiring careful design to ensure their strength and stability.

Ductility of the RC column can be sufficiently provided by confinement to the RC column core [1]. Confinement enhances the deformation capacity and energy absorption, making the columns more resistant to extreme forces such as earthquakes.

Various external column strengthening methods have been developed, one of which involves using a series of thin-walled steel tubes in circular shapes to encase the concrete, known as Steel Tube Confined Concrete (STCC) [2]. According to previous research [3], STCC demonstrates exceptional advantages in resisting lateral forces, including high earthquake resistance, good ductility, and significant energy absorption capacity.

In the context of construction material innovation, one type of waste that resembles steel tubes in form is formula milk tins. According to data from the Indonesian Ministry of Environment and According to the Waste Management and Green Open Space (RTH) Data from December 2024, metal accounted for 3.24% of the total recorded waste composition [4]. Accurate tracking and detailed documentation of materials that can be reused, recycled, or repurposed are vital for reducing waste and advancing sustainable waste management strategies [5]. Formerly, the innovation in using tin waste in concrete mainly involves processing it into fibers as an additive to concrete mixtures. However, concrete with tin fibers tends to have lower compressive strength compared to concrete without tin fibers [6][7][8].

The addition of tinned fiber in concrete may weaken its strength due to several factors. First, it can disrupt particle bonding, reducing the cement paste volume and leading to insufficient paste for adequate strength. Second, weak bonding between the fiber and the concrete matrix limits effective force transfer. Third, uneven fiber distribution creates structural heterogeneity, resulting in localized weaknesses that diminish overall strength. Therefore, further research is needed to develop alternative innovations for utilizing tin waste effectively [9].

The use of formula milk tins as an external reinforcement material for simple columns holds significant potential. Based on formula milk consumption, infants over six months old can consume more than 100 grams of formula milk per day [10]. Assuming one formula milk tins weigh 850 or 900 grams, one infant can produce approximately 48 tins of waste annually. A formula milk tin with a diameter of 13 cm and a height of 16 cm can be stacked into 20 tins to form a simple column. Thus, in one year, a single infant can generate enough tin waste to encase two columns of a simple house porch.

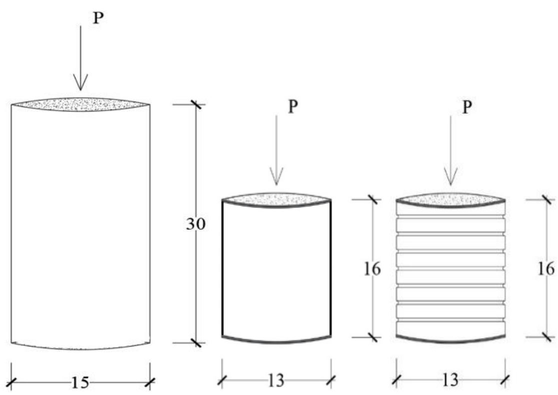
This study aims to examine the potential use of formula milk tin waste as external confinement for simple columns, providing an innovative solution to reduce waste while enhancing the performance of concrete columns.

2. Methdhology

2.1. Research Objective and Specimen Configuration

This study aims to compare the compressive strength of concrete specimens confined with formula milk tins with that of standard cylindrical concrete specimens. The confined specimens used formula milk tins with a diameter of 13 cm, a height of 16 cm, and a thickness of 0.40 mm, while the standard specimens had a diameter of 15 cm and a height of 30 cm.

The formula milk tins employed as external confinement were classified into two types: plain tins and corrugated tins, as illutrated in Figure 1. These confined specimens were design to investigate the effect of external confinement geometry on concrete compressive strength.



(a) (b) (c)

(d) (e)

Figure 1. concrete specimens
(a) standard cylindrical (b) plain tin (c) corrugated tins
(d) Example of plain formula milk tin used as confinement
(e) Example of corrugated formula milk tin used as confinement

2.2. Specimen Preparation and Casting

The research was conducted in the Civil Engineering Laboratory at Balikpapan State Polytechnic, following a structured sequence of stages: designing the concrete mix, preparing materials including the formula milk tins, mixing and casting concrete specimens, performing slump tests, curing the specimens, and finally, conducting compressive strength tests.

The study complies with relevant standards, including SNI 2493:2011 [11] for specimen preparation and curing, SNI 7394:2008 [12] for slump test procedures, and SNI 03 1974:2011 [13] for compressive strength testing.

The concrete mixture was designed based on the Indonesian concrete classification system for K-200 grade, which corresponds to a target compressive strength of 200 kg/cm² (approximately 19.6 MPa) at 28 days under standard curing conditions. The mix proportion was determined in accordance with SNI 7394:2008, ensuring compliance with national guidelines for normal-strength concrete.

The target strength refers to the characteristic compressive strength of standard cylindrical specimens with dimensions of 150 mm in diameter and 300 mm in height, tested at 28 days. The detailed mix composition per cubic meter is presented in Table 1.

Table 1. K200 Concrete Mix Composition (per 1 m³)

Material	Quantity (kg)
Portland Cement (PC)	325
Sand (PB)	731
Gravel (KR ≤ 30 mm)	1031
Water	215

Source: SNI 7394:2008

Although the mix was designed to achieve K-200 strength, the actual compressive strength obtained from standard specimens may vary due to factors such as aggregate properties, moisture condition, gradation, and curing method. These practical variations are common in experimental concrete studies and are considered in the interpretation of results.

Figure 2. Casting concrete specimens

2.3. Curing Methods

To investigate the effect of corrosion on the confined samples, two curing methods were employed. The first method involved water curing, where specimens were submerged in water for 28 days to optimize the hydration process and allow the concrete to achieve its maximum strength as shown in Figure 3 (a). The second method was air curing, where specimens were stored in a controlled open-air environment shielded from direct exposure to weather for the same 28-day period as shown in Figure 3 (b).

(a) (b)

Figure 3. Curing Methods
(a) submerged in water, called submerged specimens (-S)
(b) air curing, called unsubmerged specimens (-US)

The test specimens based on the dimenssion and curing method are labelled as shown in Table 2.

Table 2. Labelling of Specimens

Spesimen Label	Dimension (D/L)	Cylindrical Category	Curing Method
SS-S	15/30	Standard	submerged
PTS-S	13/16	Plain Tin	submerged
CTS-S	13/16	Corrugated Tin	submerged
SS-US	15/30	Standard	Unsubmerged
PTS-US	13/16	Plain Tin	Unsubmerged
CTS-US	13/16	Corrugated Tin	Unsubmerged

2.4. Compressive Strength testing

Upon completing the curing process, compressive strength tests were conducted according to SNI 03 1974:2011 [13]. Each spesimen was subjected to axial compressive loading until failure, and the maximum load was recorded. The compressive strength (1) of eachspecimen was calculated using the following equation.

$$f'_c = \frac{P}{A} \quad (1)$$

where f'_c is the compressive strength of concrete (Mpa), P is maximum applied load at failure (N), and A is the cross-sectional area of specimen (mm^2).

2.5. Correction for L/D Ratio

Due to the difference in dimensions of cylindrical concrete compressive strength test specimens, where the ideal L/D ratio is 2,0 (e.g., height 30 cm and diameter 15 cm), a correction factor is required for specimens with an L/D ratio less than 1,75. This adjustment accounts for the influence of specimen geometry on stress distribution during testing. In practice, specimens with L/D = 2,0 do not require result corrections. However, for specimens with a height of 16 cm and a diameter of 13 cm, resulting in an L/D ratio of approximately 1,23; corrections must be applied using correction tables or equations provided in the relevant testing standards. These corrections are essential to ensure the compressive strength results are equivalent to those of standard specimens.

According to the ASTM C39 *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens* [14], a correction factor is necessary when the L/D ratio deviates from the ideal value of 2.0. Table 3 illustrates the commonly used correction factors.

Table 3. Correction Factor for L/D Ratio

L/D	Correction Factor
2.00	1.00
1.75	0.98
1.50	0.96
1.25	0.93
1.00	0.87

Source: ASTM C39:2012

For L/D=1.23; the correction factor was determined using linear interpolation between *L/D* = 1.25 and *L/D* = 1.00 as presented in equation (2).

$$\text{Correction factor} = 0.93 + \frac{1.23-1.25}{1.00-1.25} \times (0.87-0.93) = 0.925 \quad (2)$$

Thus, the interpolated correction factor for L/D=1,23 is approximately 0.925. This correction was applied to ensure that the compressive strength results of the confined specimens are equivalent to those standard cylindrical specimens.

This methodology provides a comprehensive approach to exploring the potential of formula milk tins as external confinement materials, offering an innovative solution for reusing waste while improving the structural performance of simple concrete columns

3. Results and Discussion

3.1. Properties of Coarse Aggregate

The coarse aggregate used in this study was crushed stone sourced from Palu, Indonesia. Laboratory tests were conducted to evaluate its physical properties, including moisture content, mud content, specific gravity, water absorption, abrasion resistance, and particle gradation, in accordance with relevant Indonesian National Standards (SNI). The gradation curve of the coarse aggregate is presented in Figure 4.

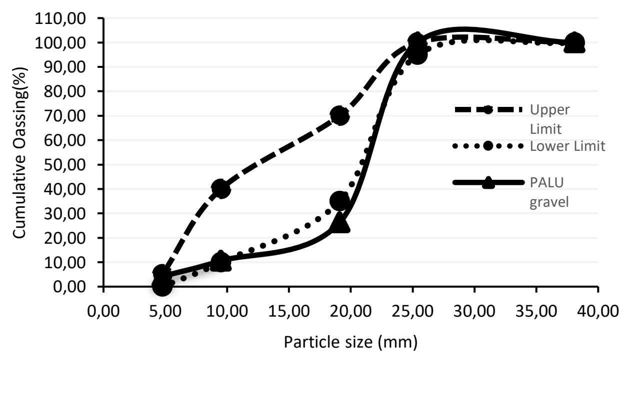


Figure 4. The gradation curve of the coarse aggregate

The test results indicate that the Palu crushed stone satisfies the required gradation limits and falls within Zone 3, with a maximum aggregate size of 40 mm. As summarized in Table 1, the moisture content, mud content, specific gravity (bulk, SSD, and apparent), and water absorption values all comply with the specified standards. The Los Angeles abrasion value of 22.68% is well below the maximum allowable limit, indicating good resistance to wear and mechanical degradation.

Table 4. Properties of Coarse Aggregate

No	Test Parameter	Reuirement	Unit	Result	Remark	Standard
1	Moistur Content Average	0.5-2.0	%	1	Complies	SNI 1971:2011
2	Mud Content	1	%	1	Complies	SNI 03-4428-1997
3	Bulk Specific Gravity	2.5-2.7	-	2.5	Complies	SNI 1969:2016
	Saturated Surface Dry (SSD) Spesific Grafity	2.5-2.7	-	2.5	Complies	
	Apparent Specific Gravity	2.5-2.7	-	2.6	Complies	
	Water Absoption	3	%	1.91	Complies	
4	Gradation	Mbh 6.5-7.10	-	6.82	Complies	SNI 03-1968-1990
5	Keausan (abrasi)	50	%	22.68	Complies	SNI 2847-2013

Overall, the results in Table 4 confirm that the coarse aggregate meets the technical requirements for use in concrete mixtures and is suitable for producing K200-grade concrete without adversely affecting the compressive strength performance of the specimens.

3.2. Properties of Fine Aggregate

The fine aggregate used in this study was natural sand obtained from Samboja. A series of laboratory tests were conducted to evaluate its physical characteristics, including moisture content, mud content, specific gravity, water absorption, fineness modulus, and particle size distribution. All tests were performed in accordance with the applicable Indonesian National Standards (SNI). The particle gradation curve of the fine aggregate is shown in Figure 5.

Based on the sieve analysis results, the fine aggregate was classified as Zone 4, indicating a relatively fine grading. As presented in Table 2, the moisture content and mud content satisfied the allowable limits specified in the standards. However, the measured specific gravity values of the fine aggregate were slightly lower than the recommended standard range. This condition may be attributed to the mineralogical composition and natural characteristics of the locally sourced sand.

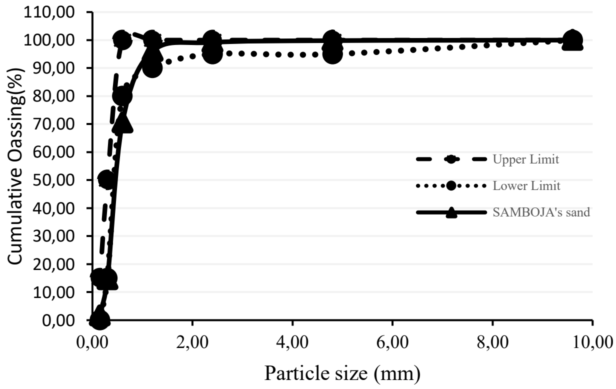


Figure 5. The gradation curve of the fine aggregate

Table 5. Properties of Fine Aggregate

No	Test Parameter	Reuirement	Unit	Result	Remark	Standard
1	Moistur Content Average	3-5	%	3	Complies	SNI 1971:2011
2	Mud Content	5	%	4	Complies	PBI-1971
3	Bulk Specific Gravity	2.5-2.7	-	2.2	Does not Comply	SNI 1969:2016
	Saturated Surface Dry (SSD) Spesific Grafity	2.5-2.7	-	2.2	Does not Comply	
	Apparent Specific Gravity	2,5-2,7	-	2.3	Does not Comply	
	Water Absoption	3	%	2.28	Does not Comply	
4	Gradation (Fines Modulus)	Mbh 6.5-7.10	-	6.82	Does not Comply	SNI 03-1968-1990

Despite this deviation, the fine aggregate was still utilized in the concrete mix to reflect realistic field conditions commonly encountered in local construction practices. Moreover, the concrete mix design was adjusted accordingly to ensure adequate workability and consistency, as confirmed by the slump test results. Previous studies have also reported that fine aggregates with lower specific gravity can still be effectively used in normal-strength concrete, provided that proper mix proportioning and quality control are applied.

Overall, the test results indicate that the fine aggregate is acceptable for use in K200-grade concrete and does not significantly compromise the compressive strength performance of the specimens evaluated in this study.

3.3. Fresh Concrete Properties (Slump Test)

The workability of the fresh concrete was evaluated using the slump test in accordance with SNI 7394:2008. The test was conducted immediately after mixing to ensure consistency in the fresh concrete properties prior to casting the specimens.


Figure 6. Slump test measuring

Figure 6 shows the measured slump value of 9.5 cm, which falls within the target range for K200-grade concrete. This result indicates that the concrete mixture possessed adequate workability, allowing proper compaction and uniform placement, including in specimens confined by formula milk tins. The satisfactory slump value also confirms that the selected mix proportions were appropriate and that the fresh concrete properties did not adversely affect the casting process.

Overall, the slump test results demonstrate that the concrete mix achieved sufficient workability to support reliable compressive strength testing and ensure consistency across all test specimens.

3.4. Compressive stregth tests

Compressive strength tests were performed on all concrete specimens after 28 days of curing in accordance with SNI 03-1974:2011. The compressive strength values were calculated following the procedures described in the Materials and Methods section, including the application of correction factors for specimens with non-standard length-to-diameter (L/D) ratios. The compressive strength results of all specimens are presented in Table 6. Subsequently, the comparison of the average compressive strength of the specimens is presented in Figure 7.

The concrete mixture was designed according to the Indonesian K-200 classification, corresponding to a target compressive strength of 200 kg/cm^{2}at 28 days. However, the experimental results of the standard cylindrical specimens showed slightly lower values, which may be attributed to material properties, aggregate gradation and curing condition.

The results indicate that concrete specimens confined with formula milk tins exhibited higher compressive strength compared to unconfined standard cylindrical specimens. This enhancement demonstrates the effectiveness of external confinement in improving the compressive performance of concrete.

Table 6. Compressive Strength Results

Code	Dimension L (mm)	D (mm)	Area (mm^2)	Compressive Load (kN)	(kg)	L/D Factor	$f'c$ (MPa)	$f'c$ (kg/cm^2)	Average (kg/cm^2)
1. Standard Specimens (SS)									
SS-S	300	150	17662,50	235,90	24055,11	1,00	13,36	164,09	
SS-S	300	150	17662,50	236,00	24065,30	1,00	13,36	164,16	182,45
SS-S	300	150	17662,50	315,00	32121,06	1,00	17,83	219,11	
SS-US	300	150	17662,50	216,30	22056,46	1,00	12,25	150,45	
SS-US	300	150	17662,50	204,00	20802,21	1,00	11,55	141,90	155,42
SS-US	300	150	17662,50	250,00	25492,91	1,00	14,15	173,90	
2. Plain Tin Confined Specimens (PTS)									
PTS-S	160	130	13266,50	215,60	21985,08	0,93	15,04	184,76	
PTS-S	160	130	13266,50	257,00	26206,71	0,93	17,93	220,24	205,84
PTS-S	160	130	13266,50	248,00	25288,96	0,93	17,30	212,53	
PTS-US	160	130	13266,50	215,10	21934,10	0,93	15,00	184,33	
PTS-US	160	130	13266,50	249,00	25390,93	0,93	17,37	213,39	199,99
PTS-US	160	130	13266,50	236,00	24065,30	0,93	16,46	202,25	
3. Corrugated Tin Confined Specimens (CTS)									
CTS-S	160	130	13266,50	236,40	24106,09	0,93	16,49	202,59	
CTS-S	160	130	13266,50	250,00	25492,91	0,93	17,44	214,24	217,79
CTS-S	160	130	13266,50	276,00	28144,17	0,93	19,25	236,52	
CTS-US	160	130	13266,50	212,30	21648,58	0,93	14,81	181,94	
CTS-US	160	130	13266,50	279,00	28450,08	0,93	19,46	239,10	215,19
CTS-US	160	130	13266,50	262,00	26716,56	0,93	18,28	224,53	

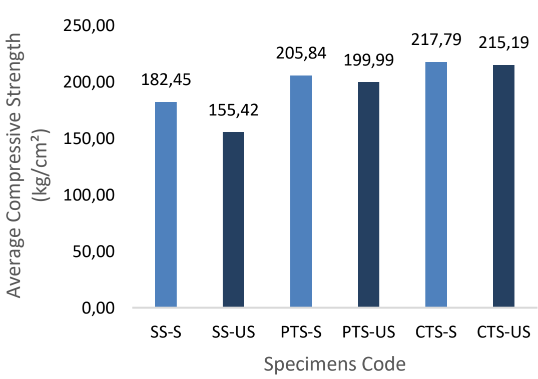


Figure 7. Average compressive strength of specimens

Specimens confined with corrugated tins achieved the highest compressive strength among all configurations, followed by those confined with plain tins. The improved performance of corrugated tins is attributed to increased lateral restraint and better mechanical interlocking between the tin surface and the concrete core, which delayed crack propagation and increased the ultimate load capacity.

In terms of curing conditions, water-cured specimens generally showed higher compressive strength than specimens cured in open air. However, the influence of confinement type was more pronounced than that of curing method, indicating that external confinement played a dominant role in enhancing compressive strength.

Overall, the results confirm that formula milk tin confinement significantly improves the compressive strength of concrete specimens, with corrugated tins providing the most effective confinement.

3.5. Effect of Tin Confinement

The effect of external confinement using formula milk tins on the compressive strength of concrete specimens was clearly observed from the test results. Compared to unconfined standard cylindrical specimens, all confined specimens exhibited higher compressive strength, indicating that the tin acted as an effective lateral restraint during axial loading.

The results in Table 6. indicate that tin confinement significantly enhaces compressive strength compered to standard cylindrical specimens. Under soaked curing conditions, plain tin confinement (PTS-S) increased srength by 12.82%, while corrugated tin (CTS-S) achived an improvement of 19.37%.

Under soaked conditions, the confinement effect became more pronounced. Plain tin confinement (PTS-US) increased strength by 28.68%, and corrugated tin confinement (CTS-US) resulted in the highest imrovement of 38.46%.

On average, the use of recycled tin confinement enhanced compressive strengt by 24.83%, demostrating its effectiveness as a passive external confinement system.

Table 6. Strength Increas Persentation effect of Tin Confinement

Code	*f'c* (kg/cm^2)	% Strength Increase
SS-S	182,451	-
PTS-S	205,845	12,82
CTS-S	217,785	19,37
SS-US	155,416	-
PTS-US	199,989	28,68
CTS-US	215,186	38,46
	Average	24,83

The presence of the tin confinement limited the lateral expansion of the concrete core, which delayed crack initiation and restrained crack propagation. This confinement effect enhanced the triaxial stress state within the concrete, allowing it to sustain higher compressive loads before failure. As a result, the confined specimens demonstrated improved load-carrying capacity compared to unconfined specimens.

A comparison between confinement types shows that specimens confined with corrugated tins consistently achieved higher compressive strength than those confined with plain tins. The corrugated surface geometry contributed to improved mechanical interlocking between the tin and the concrete surface, enhancing stress transfer and reducing the likelihood of premature debonding. Additionally, the corrugated tins provided greater resistance to local buckling under compression, resulting in more effective confinement throughout the loading process.

In contrast, plain tins provided confinement primarily through uniform radial pressure, which, although beneficial, was less effective in resisting deformation compared to corrugated tins. This difference explains the observed variation in compressive strength enhancement between the two confinement configurations.

Overall, these findings confirm that the geometry of external confinement plays a significant role in determining the effectiveness of confinement. The use of corrugated formula milk tins offers superior confinement performance compared to plain tins, making them a more effective option for enhancing the compressive strength of simple concrete columns.

3.6. Effect of Tin Confinement

The effect of curing method on the compressive strength of concrete specimens was evaluated by comparing water-cured specimens and air-cured specimens after 28 days as shown in Table 8. In general, specimens subjected to water curing exhibited higher compressive strength than those cured in open air conditions.

Table 8. Strength Increas Persentation effect of Curing Method

Specimen Code	*Soaked Strength - S*	Unsoak Strength - US	Strength Increase due to water Curing (%)
PTS	205,84	199,99	3
CTS	217,79	215,19	1.21

The curing method exhibited a measurable but relatively modest influence on the compressive strength of confined concrete specimens. For plain tin confinement (PTS), water curing increased compressive strength by approximately 2.93% compared to air curing. Similarly, corrugated tin specimens (CTS) showed a strength enhancement of approximately 1.21% under soaked curing conditions.

The relatively small difference between curing methods suggests that the external tin confinement may partially mitigate the adverse effects of limited moisture exposure. The metallic casing likely reduces surface moisture loss during early hydration stages, thereby preserving internal moisture and supporting continued cement hydration.

However, the results also indicate that proper water curing still provides marginal strength benefits. Continuous moisture availability enhances hydration products formation, resulting in a denser cement matrix and improved interfacial bonding between concrete and the confinement layer.

Overall, while confinement plays a dominant role in strength enhancement, curing quality remains an important contributing factor to optimal compressive performance.

The magnitude of strength improvement due to confinement was significantly higher than that attributed to curing variation, indicating that external restraint plays a more dominant role in strength enhancement within the investigated parameters.

3.7. Failure Pattern

Figure 8 shows the failure patterns of the tested concrete specimens, revealing a clear difference between unconfined and tin-confined configurations.

(a) (b)

Figure 8. The failure patterns of the tested concrete specimens (a) Plain Tin Confined Specimens (b) Corrugated Tin Confined Specimens

The standard cylindrical specimens (SS) showed typical brittle failure behavior characterized by sudden vertical cracking and abrupt loss of load-carrying capacity after reaching peak stress. The cracks propagated along the specimen height, indicating unrestricted lateral expansion of the concrete core under axial loading.

In contrast, specimens confined with formula milk tins demonstrated a more controlled and stable failure mode. The external tin casing effectively restrained lateral dilation, resulting in delayed crack propagation and a more gradual reduction in load capacity. Cracks in the confined specimens were generally vertical but more localized, while the tin casing remained intact or experienced limited outward deformation, indicating sustained confinement action throughout the loading process.

Distinct differences were also observed between plain tin (PTS) and corrugated tin (CTS) confinement. The corrugated tin-confined specimens maintained structural integrity for a longer duration under increasing axial load and exhibited less severe surface cracking. The corrugated geometry enhanced resistance against local deformation and improved confinement efficiency, contributing to higher peak stress and improved post-peak behavior.

3.8. Failure Pattern

The elastic response of the specimens was evaluated using the initial slope of the stress–time curve from stress-time diagram as shown in Figure 9.

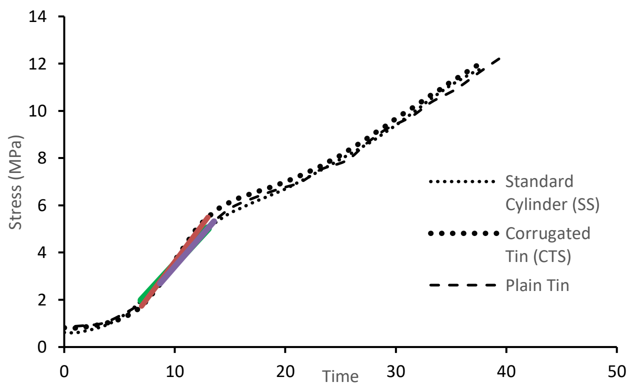


Figure 9. Elasticity Behavioure of specimens

The tangent value (tan α) in (3) was calculated to represent the relative stiffness during the early loading stage.

$$\text{Tan}\ \alpha = \frac{Opposite}{Adjacent} \quad (3)$$

The calculated tangent values are presented in Table 9.

Table 9. Elasticity of Speciments

Specimen Code	Δ*Stress in MPa* (*Y*)	Δ*Time* (*X*)	tan α
CTS	3.76	6	0.63
PTS	2.63	4.89	0.54
SS	3.05	6	0.51

The results indicate that the corrugated tin-confined specimen exhibited the highest tangent value (0.63), followed by the plain tin specimen (0.54), and the standard cylindrical specimen (0.51).

The higher tangent value observed in the corrugated tin specimen suggests enhanced stiffness due to improved mechanical interlocking and lateral restraint. The corrugated geometry likely increases the interaction surface area between the steel casing and concrete, leading to more effective confinement during the early loading stage.

In contrast, the standard specimen, without external confinement, demonstrated the lowest stiffness response. This indicates that external restraint contributes not only to peak strength enhancement but also to improved elastic performance.

These findings confirm that confinement modifies the stress transfer mechanism and delays lateral expansion, resulting in a stiffer and more stable structural response.

4. Conclusion

This study investigated the potential use of formula milk tin waste as external confinement for concrete specimens by comparing the compressive strength, failure behavior, and elasticity of confined and unconfined samples. Based on the experimental results, the following conclusions can be drawn:

1. External confinement using formula milk tins significantly enhanced the compressive strength of concrete compared to standard unconfined cylindrical specimens. This improvement confirms the effectiveness of tin confinement in restraining lateral deformation and increasing the load-carrying capacity of concrete.
2. The geometry of the confinement played an important role in determining performance. Specimens confined with corrugated tins consistently exhibited higher compressive strength, greater stiffness, and more controlled failure behavior than those confined with plain tins, due to improved mechanical interlocking and resistance to local buckling.
3. Water-cured specimens generally achieved higher compressive strength than air-cured specimens. However, the effect of external confinement was more dominant than the curing method, indicating that tin confinement can mitigate strength reduction under less optimal curing conditions.
4. Confined specimens demonstrated improved failure patterns and elasticity behavior, showing delayed crack initiation, reduced brittleness, and enhanced ductility compared to unconfined specimens.

Overall, the findings demonstrate that formula milk tins have strong potential to be reused as an alternative external confinement material for simple concrete columns. This approach not only improves structural performance but also offers a sustainable solution for reducing tin waste.

Further studies are recommended to investigate long-term durability, corrosion effects, and full-scale structural behavior to support practical implementation.

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