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Investigate the Durability and Structure Integrity of Recycled Aggregate Concrete Beam Over Time: A Literature Review

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Abstract

In term of sustainable practices, recycling plays a crucial role, particularly in the construction industry where the disposal of old structures generates significant waste. Recycling old concrete not only reduces the need for new natural resources but also eliminate waste accumulation. Numerous research study the behaviors of recycled aggregate concretes, practically focusing on the long term behaviours. A large number of studies have demonstrated that concrete made from recycled aggregate exhibits poorer long-term characteristics in comparison to aggregate from nature concrete. The long-term behaviour can be affected by three factor which is creep, shrinkage and tension stiffening. Greater management of these variables can enhance the RAC's long-term properties. The review will specifically focus on the influence of time dependent parameters i.e., creep, shrinkage, and loss of tension stiffening with time. Furthermore, it will explore the long-term deflection predicted from code used for deflection prediction, considering three codes: ACI, EC2, and the CSA code. The purpose of this paper is to enhance the understanding of long-term deflection of recycled aggregate concrete beam and evaluate the effectiveness of various factors that impact their structural performance.

Keywords: Recycled Aggregate Concrete, Long-Term Deflection, Creep, Shrinkage, Tension Stiffening.

تقييم متانة وسلامة الجسور الخرسانية المعادة التدوير للسلوك الطويل الامد/ مراجعة الادبيات

داليا علاء الدين عبد المجيد , سلطان احمد داوود , فهد عبدالله الرشودي

الخلاصة:

تعتبر إعادة التدوير دورًا مهمًا، خاصة في صناعة البناء والتشييد حيث يؤدي التخلص من الهياكل القديمة إلى توليد نفايات كبيرة. إن إعادة تدوير الخرسانة القديمة لا تقلل فقط من الحاجة إلى موارد طبيعية جديدة، بل تقضي أيضًا على تراكم النفايات. تدرس العديد من الأبحاث سلوكيات الخرسانة المجمعة المعاد تدويرها، مع التركيز عمليًا على السلوكيات طويلة المدى. لقد أثبت عدد كبير من الدراسات أن الخرسانة المصنوعة من الركام المعاد تدويره تظهر خصائص أقل على المدى الطويل مقارنة بالركام من الخرسانة الطبيعية. يمكن أن يتأثر السلوك على المدى الطويل بثلاثة عوامل وهي الزحف والانكماش وتصلب التوتر. ومن خلال دراسة السلوك الطويل الامد لهذه المتغيرات يمكن تحسين خصائص الخرسانة المعادة التدوير. تركز المراجعة بشكل خاص على تأثير العوامل التي تعتمد على الوقت، مثل الزحف والانكماش وفقدان الشد مع مرور الوقت. بالاضافة الى دراسة الانحراف طويل المدى المتوقع من الكود المستخدم للتنبؤ بالانحراف، مع الأخذ في الاعتبار الكود: ACI، EC2، ورمز CSA. أن الغرض من هذا البحث هو تعزيز فهم الانحراف طويل المدى للجسور الخرسانية المعاد تدويرها وتقييم فعالية العوامل المختلفة التي تؤثر على أدائها الهيكلي.

1.Introduction

The widespread use of concrete in construction has led to a high demand for natural aggregate, comprising about 70% of concrete mixture [1]. Interest has grown in utilized construction and demolition (C&D) waste to produce recycled concrete aggregate (RCA) to reduce environmental impact and conserve resource [2-5]. The use of C&D waste as aggregates in RCA production increased significantly during and after World War II, driven by the abundance of debris and waste from shelled cities like those in the UK and Germany [6,7]. Research has focused on various aspect of the recycled process, included separation, manufacture, and the quality of RCA, such as surface texture, shape, density, and water absorption [8]. Mechanical properties of recycled aggregate concrete (RAC), such as tensile, compression, and bending strength, was investigated [9,10]. With increase environmental awareness, research now focused on improve RCA quality through method like remove aged cement mortar and use chemical treatment to enhance mechanical characteristic [11,12]. Effort was made to improve mix procedure and incorporate mineral admixture to increase concrete strength [13,14]. However, understand the long-term behavior of RAC is crucial for maintain its strength and stability over time, consider factor like volumetric change due to hydration, load, and weather condition [15-17]. While only few studies focused on the time-dependent behavior of reinforced RAC beams, factors such as creep, shrinkage, and tension stiffening emerge as pivotal influence on long-term performance [15-17]. Code like the American Concrete Institute (ACI) 318-11 employ numerical methods to assess time-dependent displacement, while Eurocode 2 technique consider creep, shrinkage, and tension stiffening to predict long-term bending behaviour under sustained load [15,16]. This paper investigates the long-term behaviour of recycled aggregate concrete, emphasizing the roles of creep, shrinkage, and tension stiffening on structural performance, with a comprehensive analysis aimed to understanding these factor [17]. The goal is to gain evaluate the behavior of RAC over time and propose strategy to enhance its durability and sustainability in construction application.

2. Type of Deflection in Concrete

Two primary types of deflection was observed in concrete: instantons deflection and long term deflection [18].

- Instantaneous deflection occurs immediately upon the application of a load to the concrete member. It is primarily influenced by several factor such as the stiffness of the concrete and reinforcement ratio, as well as the amount and distribution of the applied load [19].
- Long-term deflection refers to the gradual deformation of the concrete member over time due to factors such as creep and shrinkage and tension stiffening [15]. Long-term deflection is significant in structures where long-term performance and serviceability to prevent excessive cracking, loss of functionality, and structural instability over time.

Long-term deflection and instantons are monitored through the planning and production stages of concrete structures in order to verify their structural integrity, safety, and durability during service life. The most common strain deformation types that can be seen in concrete in with time as presented in Figure (1)[20].

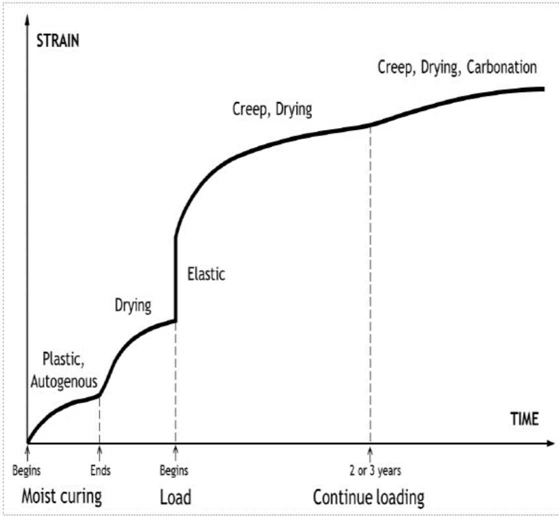

Figure (1): Type of deformation in concrete over time (Illustration not to scale)

3. Factors Effecting on The Long-Term Behaviours

3.1 Creep

It is gradual and continuing deformation of an element when subjected to consistent stress. In the case of concrete, it is the long-term deformation that occurs when the structure is under constant load [21,22]. More specifically, the strain-stress curve of concrete is not linear, and at a certain point, the strain continues rising without a significant increase in stress, this phenomenon is referred to as creep which is considered a main factor that affects long-term and causes deflection. Creep can cause excessive cracking and the gradual accumulation of deflection in structural element subjected to sustained load [3,23]. This affects the long-term behaviour of structure. Therefore, it is critical to comprehend the creep mechanism in concrete to predict its long-term deformation. Once the load is relieved, the material exhibits partial recovery to its prior shape which is known as Creep recovery [24,25], It is well acknowledged that certain parts of the beginning creep deformation can be returned, while another portion remains irrecoverable as presented in Fig.(2). Concrete strain recovery classified two components: immediate recovery strain and gradual recovery strain [25]. Immediate-recovery strain occurs after load removal, linked to concrete elastic modulus during unload. Gradual recovery strain refers to strain during creep-recovery after load removed [25]. ASTM C512 (2015) offer various description for concrete creep deformation: "Creep strain" signifies strain development over time under continuous load. "Specific creep" quantifies creep strain per unit stress, while "creep coefficient" represent creep strain to elastic strain ratio. "Compliance" is elastic deformation and creep under specific stress. In recycled aggregate concrete (RAC), several factor influence creep: load duration, concrete mixture properties, aggregate quality and percentage, humidity, and temperature [3,25]. addition the coarse aggregate with recycled aggregate (RA) increase creep deformation compared to normal concrete (NC) [9,22]. This increase is attributed to lower modulus of elasticity, higher porosity, and increase water absorption capacity, due to adhered mortar. Additionally, a study on water-to-cement (w/c) ratio impact on RAC creep deformation found that higher w/c ratio leads to increase creep [26,27]. This is attributed to reduced porosity, more uniformly hardened cement paste matrix, and a larger interface transition zone between aggregate and cement paste. Additionally, Several studies show that during the initial 15 days after loading, 18-38% of the entire creep over 20 years occurs while within the first ninety days, over 70 percent of the creep gets place, and roughly 83% of the total amount of creep happens during the first year[28]. Also research discovered that the creep of RCA concrete may be accurately estimated by employing the normal concrete models described in ACI-209R, together with the incorporation of an adjustment factor t_0, the creep coefficient at time as well as the maximum creep coefficient for RAC subjected to constant stress are calculated using the following equations [29]:

$$\emptyset_{RAC}(t) = \frac{(t-t_0)\psi^{cr1}}{[\psi^{cr2}+(t-t_0)\psi^{cr1}]}\emptyset_{u,NA} \quad \text{.......(1)}$$

$$\emptyset_{u,NA}\frac{\boldsymbol{\alpha_{cr}(\emptyset_{u,na}+1)E_{c,RAC}}}{\boldsymbol{E_{C,NA}-1}} \quad \text{....................(2)}$$

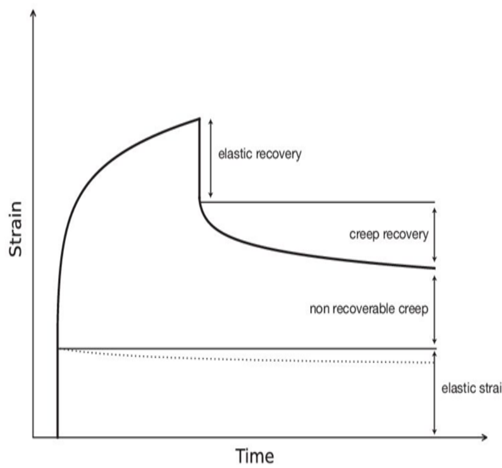

Figure (2): Creep and Creep Recovery Phenomena

$$\alpha_{CR} = \beta_{CR0} + \beta_{CR1}\frac{F'_{c\,RAC}}{F'_{c\,NA}} + \beta_{CR2}R \ldots(3)$$

Where:

ψ^{cr1} and ψ^{cr2} = time factor of creep.

$\emptyset_{u,NA}$ = ultimate concrete creep coefficient.

$\emptyset_{RAC}$ = ultimate recycled aggregate concrete creep coefficient.

α_{cr} = adjustment factor for proposed creep.

β_{CR0}, β_{CR1} and β_{CR2} = un-normalised coefficients of creep regression.

$\boldsymbol{E_{C,NA}}$ and $\boldsymbol{E_{c,RAC}}$ = modulus of elasticity of concrete and RAC.

$F'_{c\,NA}$ and $F'_{c\,RAC}$ = normal concrete and RAC compressive strength.

R = aggregate ratio (decimal form).

3.2 Shrinkage

Shrinkage denotes volume change in concrete due to water evaporation, cement hydration, and carbonation [22]. It significantly affects structure concrete, lead to stress redistribution and increase deflection, primarily influence long-term deflection [22]. Generally, there are four shrinkage types: Autogenous, carbonation, plastic, and drying [30,31]. Autogenous shrinkage involves chemical shrinkage and self-desiccation mechanism. Chemical shrinkage occurs when hydration product has smaller volume than the hydrated product, while self-desiccation result from water absorption through cement hydration, in low w/c ratio concrete [32]. Carbonation shrinkage arise when carbon dioxide combines with calcium hydroxide, induce shrinkage $Ca(OH)_2$ dissolution [33]. Plastic shrinkage occurs when concrete remain in a plastic state, lead to water absorption and surface crack. Drying shrinkage emerge when moist curing cease, cause water to evaporate from the cement paste into the surrounding. This can generate tensile stress, reduce volume and form crack, ultimately cause deflection even without external force [22]. Various factor contributes to the occurrence of shrinkage in concrete, include ambient temperature, relative humidity, and curing time [34]. The choice of aggregate type is also a significant factor affect shrinkage. When recycled aggregate (RA) are used instead of natural aggregates (NA), the shrinkage characteristic of the concrete is impacted due to difference in the aggregate stiffness, which is a primary factor influence deformation [20]. Experimental studies have demonstrated that increase the substitution of RA result in a substantial increase in shrinkage, possibly attributed to the reduced elastic modulus of recycled concrete aggregate (RCA) [22,35]. An investigational examination A comparative analysis was carried out to determine the water absorbing characteristics of limestone gravel and concrete refuse, with the concrete waste demonstrating a considerably higher capacity than the limestone aggregate. The strongest effects are observed in the drying shrinking, which significantly diminishes as the percentage of fine limestone increases [36]. Various code and standard are employed by engineer to evaluate the time-dependent behaviour in concrete structure, for instance, Eurocode 2 (EN 1992-1-1) Part 1-1 focuses on general design rule for building, including provision for the considered time-dependent effect such as shrinkage and creep, also AASHTO for bridge Design Specification shows time-dependent effects in concrete bridge structures, such as shrinkage and creep, to ensure long-term performance and safety. while ACI 209R-92 offer method for estimating the effect based on material properties, environmental condition, and structure characteristic. code and standard considered as essential reference in designing concrete structure, providing guidance on how to account for time-dependent behaviour to ensure safety. A researcher discovered that the shrinkage of RCA accurately estimated by employing the normal concrete model [39] to described the utilisation of ACI-209R model is combined with factor to . The provided equation for determining the shrinkage coefficient at a specific time $t = to$.

$$\varepsilon sh_{Rac}(t) = \frac{(t-to)}{[\psi_{sh}+(t-to)]^{\varepsilon shu,na}} \quad \text{..........(4)}$$

$$\varepsilon sh_{u,Rac} = \frac{\alpha_{sh}(\varepsilon sh_{u,na}+1)E_{\mathbb{C},rca}}{E_{c,na}-1} \quad \text{.............(5)}$$

$$\alpha sh = \beta sh0 + \beta sh1 \frac{fc`rca}{fc`na} \beta sh2 \, R \ldots\ldots\ldots(6)$$

Where:
ψ = shrinkage factor for time depends.
$\varepsilon sh_{u,na}$= NC`s ultimate shrinkage.
α_{sh} =shrinkage factor
$\beta sh0$, $\beta sh1$ and $\beta sh2$ = un-normalised coefficient of shrinkage.

3.3 Tension Stiffening

It is the concrete's capacity to withstand tension forces, despite the presence of crack [21,23]. To explain tension stiffening by Considering the uniaxially loaded on the tension member as illustrated in Fig.(3a) [37]. The process consists of two separate stages: pre-cracking and post-cracking. In the pre-cracking stage, as the load on the tension member increases, the concrete's tensile stress rises until it reaches the point of tensile strength. This leads to the initiation of cracking as shown in Fig.(3b). During the initial stage, the member maintain high stiffness as the concrete and steel are well-bonded, ensure structure integrity. However, as crack occur, stress in the concrete at the crack site diminished to zero, while stress increase with distance from the crack due to steel bond. Consequently, local stiffness decreased due to compared integrity and load capacity. In the post-cracking stage, slip at the concrete and steel interface near the crack wide the crack. Continues load can generate more crack at different distance from the initial one, as illustrated in Fig.(3d). In this stage, the stiffness of the member continues to decrease as more cracks form and propagate, causing local stress redistribution and a reduction in load-bearing capacity [18]. Also, a study by Gilbert investigated how shrinkage and creep impact on stiffening of reinforced concrete structures over both short and long-term durations [38]. Shrinkage before loading causes a decrease in the cracking load and leads to a gradual build of tension in the concrete, ultimately reducing tension stiffening. while, tensile creep reduces the concrete in tension, transferring some of the tensile force to reinforcement, further decrease the tension in 2010 experimental explored the effects of increased load on deflection and crack development in concrete structure. The study noted that over time, tension stiffening diminishes, resulting in reduced structural stiffness and increased deflection. [38] Another investigation analysed the impact of long-term shrinkage on the tensile behaviour of reinforced concrete elements. It was found that after 5.3 years, accumulated shrinkage significantly affected deformation behaviour and tension stiffening. Shrinkage resulted in underestimated cracking loads, particularly with higher reinforcement ratios, with tension stiffening decreasing by approximately 40% for reducing reinforcement percentages and around 80% for increasing reinforcement ratios due to shrinkage.

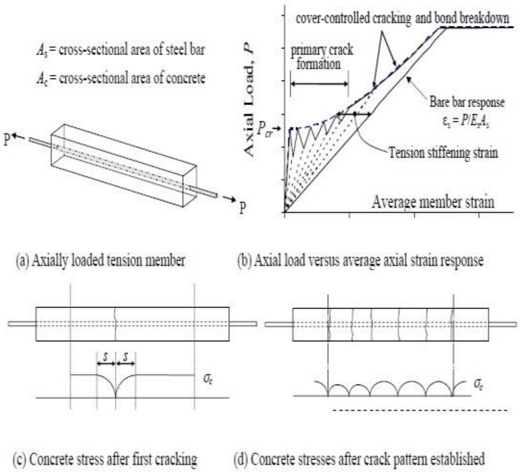

Figure (3): Phenomena of tension stiffening

4.Code Procedures for Long-Term Deflection

4.1 ACI Code 318

The American (ACI) has implemented a method within ACI-318 for assess the short-term deformation of RC beam. This technique integrates both uncracked and fully cracked section, incorporate tension stiffening into the calculation of the effective moment of inertia (Ie) of the beam. This is achieved through interpolation among the uncracked (Ig) and cracked (Icr) values.
M_{cr} = moment cracking
M_a = the moment applied.
I_g = gross moment of inertia.
I_{cr}= (fully-cracked) moment of inertia.

$$I_e = \left(\frac{M_{cr}}{M_a}\right)^3 I_g + [1 - \left(\frac{M_{cr}}{M_a}\right)^3 I_{cr} \leq I_g \ldots(7)$$

$$f_r = 0.62\sqrt{F_c'} \ldots\ldots\ldots(8)$$

$$M_{cr} = \frac{f_r I_g}{y_t} \ldots\ldots\ldots(9)$$

$$y_u = \frac{\frac{bh^2}{2} + (n-1)(A_S\, d + A_S'\, d)}{bh + (n-1)(As + A`_S)} \ldots\ldots\ldots(10)$$

$$I_g = \frac{bh^3}{12} + bh\left(\frac{h}{2} - y_u\right)^2 + (n-1)A_S(d - y_u)^2 + (n-1)A`s(yu - d`)^2 \ldots\ldots(11)$$

$$I_{cr} = \frac{by_C^3}{12} + nA_s(d - y_C)^2 + (n-1)A`_s(y_C - d')^2 \ldots\ldots(12)$$

$$I_e = \left(\frac{M_{cr}}{M_a}\right)^3 I_g + \left(1 - \left(\frac{M_{cr}}{M_a}\right)^3\right) I_{cr} \leq I_g \ldots(13)$$

$$\Delta_i = k\frac{M_a L^2}{E_c\, I} \ldots\ldots\ldots(14)$$

K = factor based on loading circumstances and support fixity
I = I_g when $M_a \leq M_{cr}$ (for un-cracked section)
I = I_e when $M_a > M_{cr}$ (for cracked section)

To determine the time depended deflection (Δl) that occurs over a period of time due to continuous loading by utilizing Equation (Branson, 1977). Adding a multiple factor (λ) to the immediate deflection, the factor accounts for the total effect of both shrinkage and creep of deflection with time. The AcI factor curve shown in Fig.(4).

$$\lambda = \frac{\zeta}{1+50p'} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(15)$$

ζ = is a factor that changes with time and can be ascertained from Figure4.

$\rho`$ = reinforcement ratio in compression zone = $A_s`/bd$

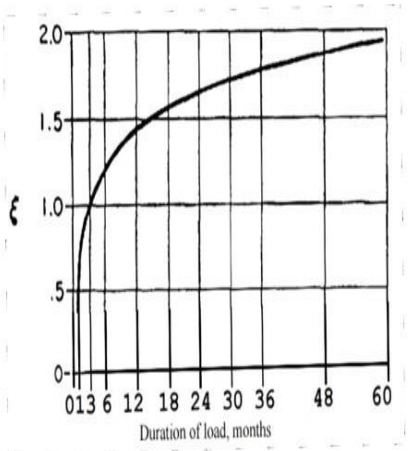

Figure (4): The ACI multiplier factor used to calculate long-term deflection

4.2 Eurocode 2

The Concrete Society and The Concrete Centre released technical documents in 2005 and 2006, respectively, that promoted for a simplified method, in accordance with Eurocode 2, for estimating the potential long-term displacement of a beam. This approach utilizes an elastic analysis of the section in an effort to simplify computation by modifying the section's rigidity to take into account variables such as creep, shrinkage, and cracking. The approach seeks to enhance the accuracy of predictions by including these effects, specifically by calculating an adjusted effective modulus of elasticity(Ec*eff).

The basic component of this technique is a constant value K = 0.5, utilized to incorporate the effects of shrinkage and cracking. This constant value simplifies calculations for practical applications; its efficacy will be assessed in the following section by comparing it to experimental findings.

$$E^*_{c,eff} = \frac{kE_C}{1+\emptyset(t,t_0)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(16)$$

$$\frac{1}{r} = \frac{M_a}{E^*_{ceff} I_u} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(17)$$

4.3 CSA Code

The Canadian Standard Association recommends using the multiplier factor approach (CSA-A23.3) to estimate long-term deformation of concrete member under continues service loads, similar to the ACI-318 approach. To estimate this deflection:

$$\Delta_l = \left(\frac{S_t}{1+50p'}\right)\Delta_i \ldots\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots(18)$$

Table (1) shows that the value of (S_t) grows with time of the sustained load, reaching a maximum value of two for t ≥ five years.

Table (1): Multiplier factors amount of (S_t) for long-term deflection predictions.

Sustained load period	S_t
Three Months	1.0
Six Months	1.2
Twelve Month	1.4
Five year or more	2

4. Previous study of Long-term Behaver of Recycled Aggregate Concrete Effecting by Creep, Shrinkage and Tension Stiffening

Kou et al. [39] examined the shrinkage of concrete that was cured in water steam while using different amounts of RCA and fly ash. Steam curing demonstrate superior control over concrete shrinkage in comparison to water curing, result in an average shrinkage reduction of 15%, regardless of replacement amount and fly ash concentered.

While Khatib [40] investigates concrete containing crushed brick CB as fine recycled aggregate has better exhibit to shrinkage behavior compared to concrete with RCA. Even at 100% replacement of fine aggregate with CB, the reduction in strength is only 10%, indicating its suitability for long-term behaviour. Additionally, after 28 days of curing, both RAC and CB contribute to higher strength development and more shrinkage in concrete containing RCA or CB.

Wu and Gilbert [37] illustrates the impact of shrinkage and creep in tension stiffening through a study that examines the behaviour of tension stiffening in structures made of reinforced concrete subjected to both short-term and long-term loading.

Domingo-Cabo group [41] in 2009, conducted an experiment to determine the effect of incorporating recycled aggregate derived from building rubble and concrete demolition CDW on the concrete's long-term deflection. Natural aggregates NA were substituted with RCA at percent substitution rates of 20%, 50%, and 100%. In addition to the fine natural aggregate, the cement quantity and water-cement ratio remained unchanged. The findings suggest that deformation in RAC increased significantly after 180 days, with the substitution percentage having a significant impact on deflection. In particular, when coarse NA was completely substituted with RCA, creep deformation increased by 51% and contraction increased by 70% in comparison to NC.

Amorim et al. [42] studies the humidity level of concrete contain (RCA) under various curing circumstance: immersion in water curing (IWC), wet lab curing (WLC), curing in dry laboratory (CDL), and curing outdoor (COD). and for various replacement ratio 0%, 20%, 50%, and 100% of RCA. This performance is being compared to that NC that subjected to similar curing circumstance. The variation between the RCA and NC result were measured based on the rate of substitution and the method of curing. All The specimen exposed to controlled environment in the lab on Day 1 of the curing process. The laboratory test, with a relative humidity 60% and an ambient temperature of 20 degree Celsius, resulted in the specimens having greater shrinkage strain when compared to other exposed to different condition. The specimen showed a significant rise in shrinkage to 60% while the amounts of replacement 100% RCA was used. drying shrinkage decreased due to the higher humidity level under different curing condition. When comparing specimen cured under different condition, the utilization of RCA in these cases resulted in lower negative influences on shrinkage.

Manzi et al. [43] examines the effects of coarse and fine RA on the physical as well as mechanical characteristic of structural concrete over the long term. The research revolved on the optimising of the design of concrete mixes in order to attain significantly elevated compressive strengths while integrating a substantial percentage of RCA, which varied between 27% and 63.5% of the overall aggregate content. Additionally, time-dependent properties like creep and contraction are examined. Utilisation of RCA has a detrimental effect on the shrinkage strain of concrete, as demonstrated by the results. Specific creep results, on the other hand, indicate that RCA-containing concrete exhibits greater creep than natural NC concrete.

Choi and Yun [44] investigate the flexural performance and long-term (RAC) beams subjected to prolonged loading for a period of 380 days. Specimens of three (RC) beams were fabricated, with various amounts of replacement for each beam: 50% RFA, 100% NA, and 100% RCA. The beam is under a sustained strain equivalent to fifty percent of its nominal flexural capacity. The long-term deflection measure due to creep and shrinkage were compared against prediction from the ACI 318 Code. The calculated prolonged deformation uses the modified ACI method with the experimental result.

Cartuxo group [45] assesses how two types of superplasticizer (SP) affect concrete behaviour when using fine recycled concrete aggregate (FRCA). Concrete mix were divided into three group: C0 (no SP), C1 (standard SP), and C2 (high-performance SP). Various level of natural sand replacement with FRCA were examined: 0%, 10%, 30%, 50%, and 100%. All mix had identical particle size distribution, adjusted water/cement ratio to maintain similar slump, and avoided pre-saturation of FRCA. Result show that incorporates FRCA increase shrinkage and creep deformation, with effect varying with curing age. Concrete with natural sand exhibit greater stabilize of creep deformation compared to FRCA mixe. Initially, superplasticizer increase shrinkage, but after 91 days, they decrease it, especially with the high-performance, which enhance creep resistance. However, FRCA incorporation diminished the effect of superplasticizer.

Knaack and Kurama [46] analysised 18 beams, each with vary level of aggregate replacement, reinforcement detail, and concrete age upon load. The Find revealed that higher level of recycled concrete aggregate (RCA) result in noticeable increase in both immediate and long-term deflection compared to beam with normal concrete (NC), although this effect diminishes with increase crack. Furthermore, RCA beam demonstrated greater creep and shrinkage deformation. While ACI 318 and Eurocode generally provided accurate estimate for immediate deflection, they significantly underestimated long-term deflection, especially for uncracked beam. However, for cracked beam, ACI 318 slightly underestimated while Eurocode slightly overestimated long-term deflection. the accuracy of design method did not significantly different between NC and RCA concrete beam.

Oad team [47], examines how reinforced concrete beam perform over a year when NA replaced with aggregates from demolished concrete. Result shows that using demolished concrete in new concrete yield promising result over 12 months of continuous load, with a slight increase in deflection (4.96%) and a minor decrease in peak load (2.33%).

Then in 2019, his team illustrates the effects of long-term loading on reinforced concrete beam that replaced NA with RA from old concrete [48], an experiment conducted on nine reinforced concrete beam under sustained load condition, six beams were constructed using NA, while the others contained 50% RCA. Each of them was cured for 28 days. An experiment was conducted on three beams to investigate the immediate deformation of the concrete. After 6 months, the RAC was investigated to evaluate the long-term deflection, The results show that the RAC has a 22.21% higher deflection.

A study by Zhu et. al. in 2020 investigated the long-term performance of reinforced concrete beam with various ratio of RCA [49]. The beam dimension 120 mm in width, 260 mm in depth, and 2000 mm in length, were tested over 3045 days with clear span of 1800 mm. The w/c ratio was 0.46, with a compressive strength 30 MPa, temperature 20 ± 2℃, and relative humidity above 95%. The result indicated that the deflection at the mid-span of beam containing 50% and 100% RCA remained relatively constant during initial loading. However, after 200 days, the total deflection of the 100% RCA beam higher that of the 50% RCA beam. Deformation curves for beams with 0% and 50% RCA were constant over time, while beam with 100% RA showed significant variation due to aged mortar adhered in the RCA. Furthermore, RAC beam exhibited higher creep and shrinkage during sustained loading, resulting in unstable deformation. Compared to NC beam, the overall deflection at the end of the 3045days increased by 10.2% and 21.3% for beam containing 50% and 100% RCA, respectively.

Zhang team [50] used 100% (FRAC) for the subject of an experiment in which recycle powder (RP), recycle fine aggregate (RFA), and RCA were utilized. An analysis was conducted to determine the effect of four aggregate combinations on the prolonged behaviour over a period of 180 days. Utilizing an FRA mixture had an effect on the prolonged behaviour properties of concrete, according to the findings. However, when FRA was combined with completely recycled fine aggregate, the outcome was comparatively unfavorable in contrast to the use of FRA in isolation. Furthermore, the incorporation of RP resulted in a reduction of the mechanical properties of FRAC by 5%–17%. Additionally, an increase in RP content from 10% to 30% resulted in a 3%–13% reduction in the contraction strain of FRAC over 180 days. In order to examine the prolonged behaviour a suitable long-term contraction model for FRAC was constructed. By integrating a modification coefficient that accounts for aggregate combination and RP contents, this model significantly improves upon existing models' ability to forecast long-term shrinkage behaviour.

Sryh and Forth in 2022, [9] investigates how the flexural performance of cracked (RAC) beam evolve over time, employ (CDW) as (RCA). Various specimen with ratio (0%, 50%, and 100%) were imposed to sustained load for 90 days. The find indicated that higher level of RCA led to reduce strength and increase short-term and long-term deflection compare to beam without recycled aggregate (NC). Moreover, there was an observed increase in creep, shrinkage, and loss of tension stiffening in tension specimen reinforced with RAC. Eurocode 2 predicted underestimate the experimental deflection of RAC beam, but adjust stiffening factor (β) to 0.4 for 50% RAC and 0.3 for 100% RAC resulted in more accurate prediction within approximately 1%. Consequently, the study recommends lower the β factor from 0.5 for NC and 0.4 for RAC with 50% while and 0.3 for RAC with 100% replacement to enhance the prediction of long-term deflection in RAC beam.

An experimental investigation was conducted in 2023 to assess the prolonged behaviour of prestressed reinforced concrete (PRAC) beams [51]. The study investigates different level of RCA substitution in concrete beam and analysised various factor in their finite element analysis (FEA). These factors included the proportion of RCA replacement, concrete strength, amount of reinforcement, degree of prestress, sustained load, creep, shrinkage, and tendon relaxation. The beam was subjected to a constant load for 1000 day. For beam with 50% RCA substitution, tendon relaxation contributed 15% to long-term deflection and concrete creep contributed 44%. Conversely, for beam entire replaced with RCA, tendon relaxation still contributed 15%, but concrete creep decreased to 36%. This suggest that as the RCA replacement ratio increase, the impact of concrete creep on long-term deflection diminished. Furthermore, the behaviour of tendon relaxation remains consistent across different level of replacement ratio. In summary, increase RCA in PRAC beam can reduce the effect of concrete creep on long-term deflection.

5. Conclusion:

- The rise in recycled aggregate replacement correlates with increased creep and shrinkage deformation, primarily due to the amount of old attached mortar.
- -Mineral admixture show promise in controlling creep and shrinkage, affecting deflection over time.
- Long-term deflection is higher in RAC compared to natural NC, with both long-term deformation and crack width increasing with higher recycled aggregate percentage.
- Code method for calculate long-term deflection in RAC need adjustment for accuracy.
- An empirical model for predicted creep and shrinkage in RAC was developed, adapted from conventional concrete model.
- External factor like temperature and humidity effecting creep as well as shrinkage, result to increased deflection in recycled aggregate concrete.
- The study explains the tension stiffening behavior in RC structure under short and prolonged loading, including the effect of creep and shrinkage.
- According to Eurocode2, modification was suggested to adjust the value of (ζ) to account stiffening characteristic exhibited by beam with recycled aggregate (RA). Additionally, the study focuses the impact of recycled aggregate concrete (RAC) on concrete shrinkage under various curing condition.
- As the proportion of (RCA) in prestressed reinforced concrete (PRAC) rises, the long-term displacement result of concrete creep diminishes.

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