A review on torsional behavior of high-performance concrete beam

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Abstract:

The main points discussed in the summary are emphasized in this study, referencing important studies, and setting the stage for an in-depth exploration of the high-performance concrete beams' torsional behavior. The utilization of high-performance concrete (HPC) in structural engineering has witnessed a significant surge owing to its exceptional mechanical properties and durability. This analysis examines the torsional behavior of HPC beams, aiming to synthesize existing knowledge from empirical studies, experimental investigations, and theoretical models. The trend toward employing concrete with compressive strengths exceeding 80 MPa, reinforced by high-strength steel, raises pertinent questions about the interplay between increased material strength and structural ductility. To address this issue, the study evaluates the current design critically codes' efficacy in balancing strength and ductility, particularly focusing on minimum reinforcement regulations. Studies by Rasmussen, Baker, Lopes, Bernardo, Chiu, Ismail, Yoon, and more sources are important sources for this analysis. Their comparative analyses between normal concrete and HPC beams reveal intriguing insights. While HPC beams exhibit enhanced torsional stiffness and stress in reinforcement, they also display an increased tendency towards brittleness post-cracking, impacting ductility. Notably, dependencies on reinforcement ratios and the proportion of transverse to longitudinal reinforcement in HPC beams significantly influence post-cracking strength and failure modes. In addition to empirical investigations, the article explores the numerical techniques Rahal, Collins, Chalioris, and Bernardo put out to forecast predict, and estimate the torsional behavior of HPC beams. These models showcase potential in estimating initial stiffness, cracking moments, and strengths, laying the groundwork for understanding and predicting torsional responses. Overall, this analysis highlights the complex relationship between enhanced material strength and potential reductions in ductility in HPC beams. It illuminates crucial facets of HPC beam behavior under torsional loading, calling for a reevaluation of design codes to ensure the integrity of these structures while maximizing their superior mechanical properties.

Keywords: torsional behavior, High-Performance Concrete (HPC), Concrete Beams, Critical Torsional Strength, history.

مراجعة على السلوك الالتوائي للعوارض الخرسانية عالية الأداء

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خلاصة:

تم التركيز في هذه الدراسة على النقاط الرئيسية التي تمت مناقشتها في الملخص، حيث تشير إلى دراسات مهمة، وتمهيد الطريق لاستكشاف متعمق للسلوك الالتوائي للعوارض الخرسانية عالية الأداء. شهد استخدام الخرسانة عالية الأداء (HPC) في الهندسة الإنشائية طفرة كبيرة بسبب خصائصها الميكانيكية الاستثنائية ومتانتها. يفحص هذا التحليل السلوك الالتوائي لحزم HPC، بهدف تجميع المعرفة الموجودة من الدراسات التجريبية والتحقيقات التجريبية والنماذج النظرية. إن الاتجاه نحو استخدام الخرسانة ذات قوة ضغط تتجاوز (80) ميجا باسكال، والمعززة بالفولاذ عالي القوة، يثير أسئلة وثيقة الصلة حول التفاعل بين زيادة قوة المواد والمرونة الهيكلية. ولمعالجة هذه المشكلة، تقوم الدراسة بتقييم فعالية التصميم الحالي للأكواد في تحقيق التوازن بين القوة والليونة، مع التركيز بشكل خاص على الحد الأدنى من لوائح التعزيز. تعتبر الدراسات التي أجراها راسموسن، وبيكر، ولوبيز، وبرناردو، وتشيو، وإسماعيل، ويون، وغيرهم من المصادر مصادر مهمة لهذا التحليل. تكشف تحليلاتهم المقارنة بين الخرسانة العادية وعوارض (HPC) عن رؤى مثيرة للاهتمام. في حين أن كمرات (HPC) تظهر صلابة الالتوائية معززة وإجهادًا في التسليح، فإنها تظهر أيضًا ميلًا متزايدًا نحو الهشاشة بعد التشقق، مما يؤثر على الليونة. والجدير بالذكر أن الاعتماد على نسب التسليح ونسبة التعزيز العرضي إلى الطولي في حزم (HPC) يؤثر بشكل كبير على قوة ما بعد التكسير وأنماط الفشل. بالإضافة إلى التحقيقات التجريبية، يستكشف المقال التقنيات العددية التي استخدمها رحال وكولينز وتشاليوريس وبرناردو للتنبؤ وتقدير السلوك الالتوائي لحزم (HPC). تعرض هذه النماذج إمكانية تقدير الصلابة الأولية ولحظات التشقق ونقاط القوة، مما يضع الأساس لفهم الاستجابات الالتوائية والتنبؤ بها. بشكل عام، يسلط هذا التحليل الضوء على العلاقة المعقدة بين قوة المواد المحسنة والتخفيضات المحتملة في الليونة في حزم (HPC). إنه يسلط الضوء على الجوانب الحاسمة لسلوك شعاع (HPC) في ظل التحميل الالتوائي، مما يدعو إلى إعادة تقييم رموز التصميم لضمان سلامة هذه الهياكل مع تعظيم خواصها الميكانيكية الفائقة.

الكلمات المفتاحية: السلوك الالتوائي، الخرسانة عالية الأداء (HPC)، الكمرات الخرسانية، القوة الالتوائية الحرجة، التاريخ.

Introduction:

Using stronger steel and concrete in reinforced concrete constructions is becoming more and more common. In the near future, more members will use 600 MPa yield strength steel reinforcement and concrete that has a compressive strength more than 80 MPa. These members' small weight and slender build, together with the more straightforward way their reinforcement is arranged, are the reasons for their newfound appeal. Still, it is necessary to examine the decrease in ductility brought on by the strength increase. Therefore, it is necessary to confirm if the design codes now in use can effectively govern the strength-ductility balance. In light of the minimum ductility requirement, it is extremely crucial to go over the specifications pertaining to the minimum reinforcement ratio.

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Contrasting the torsional characteristics of concrete reinforced beams composed of regular and high-strength, Rasmussen &Baker [1] and Bernardo and Lopes [2] found that using high-strength concrete improved the reinforcement's stress and torsional stiffness but increased its propensity to fracture. Chiu et al.'s [3] investigation of the impact of the lowest reinforcement ratio in both Cross-sectional and longitudinally involved absolute torsion testing upon beams composed Comprising both regular and strengthened concrete. These authors indicated that, based on their experimental findings, the proportion of transversal to longitudinally reinforcing as well as the overall reinforcement ratio in both the longitudinally and in opposition planes significantly affected the strength after breaking. or the ductile failure mode. In comparison to members formed of regular concrete, this dependency was more pronounced in the high-strength concrete members. High-strength concrete was found to promote the development of brittle behavior beyond the torsional strength, according to Ismail [4], who reviewed the literature on prior torsion tests, and Yoon et al. [5], who conducted an experimental investigation into the impact of high-strength reinforcement.

Literature review:

Faisal F. Wafa, Atef H. Bakhsh, and Ali I. Akhtaruzzaman, 1990 [6] Test results under straight torsion on thirteen rectangular, simple, high-strength concrete beams are displayed. The stated strength of the concrete varied between 40 and 90 Mpa (5800 to 13,000 psi), and this was variable. In addition to Type I Portland cement, High crushing strength coarse particles and high modulus of fineness sand were used. In addition to a smooth surface, the simple, concrete beams with high strength under torsional collapsed abruptly and brutally. If the splitting tensile strength is thought to be an accurate depiction of the tensile strength of concrete. Then For simple high-strength concrete beams, the torsional capacity can be predicted using the skew-bending hypothesis.

G. Baker and L. J. Rasmussen, 1995 [7] the way beams made of high-strength concrete (HSC) and reinforced standard concrete (NSC) behave in true torsion, is investigated in this paper. The only variables in the twelve completely over-reinforced beams in the examination group were those that affect the beams' Strength of concrete and a torsional power capacity. As a result, for every beam, the proportions for a cross-section, reinforcement strength, as well as the measurements for reinforcement remained consistent. The concrete's strength varied from 36 to 110 MPa or 5,220 to 15,959 pounds per square inch. The sequence of tests has shown the benefit of employing HSC. Compared to NSC, using HSC for supplied force and its section produces increased rigidity in the torso, reduced along with a greater ultimate torsional capacity, a wider crack, and reduced reinforcing stresses.

Talal A. Radain, Tamim A. Samman, and Samir A. Ashour 1999 [8] this article examines the behavior of high-strength concrete (HSC) reinforced deep beams under natural torsion. There were twenty beams during the sequence of tests. The factors were the concrete's compressive strength and span-depth ratio (L/h). L/h of 1 to 5 and concrete's 54 and 94 MPa strengths of compression were employed. There was no change in the reinforcement of both transversely and longitudinally ratios. The findings of the tests indicated that when concrete strength increases and L/h decreases, torsional strength and stiffness increase as well. Deep beam conditions are taken into account by modifying the theory of the softened truss model. The theoretical model predicts the torsional power and distortions of the components during their post-cracking stress history. Theoretical forecasts utilizing the updated model understated the torsional strength in tiny L/h beams. The test findings are used to develop a partially empirical formulation for deep beam action modeling. The results of the tests coincide with the forecasts rather well.

N.-E. Koutchoukali, Abdeldjelil Belarb, 2001 [9] The effect of strong concrete on the torsional strength of reinforced concrete (RC) beams was investigated through the testing of nine full-size beams under pure torsion. The durability of the concrete along with the quantity of reinforcing served as the study's primary parameters. Normal strength concrete to all strong concrete classes (designated as 50, 60, 80, and 95 MPa) were all available. The range of reinforcing amounts was lower than the required level for the supposedly fair state, which is the result of projected concrete crushing occurring at the same time as steel yield. There was an equal amount of reinforcement added to both the longitudinally and opposite axes. To maintain the concrete struts' approximate 45-degree slope. The findings demonstrate that the ACI318-99 minimum level of reinforcement is insufficient for strong RC beam stable torsion, as well as a fresh expression is offered. It has been shown that the torsional resistance of under-reinforced beams is independent of concrete's durability and that the amount of longitudinally reinforced steel is more effective in reducing the width of cracks than the amount of reinforcement along the transverse axis (stirrups).

Zhang, Yunjing, 2002 [10] The main goal of this research is to create more accurate analytical techniques for predicting and verifying reinforced concrete beams' quadratic reaction to torsion, particularly for high-strength concrete. Finite element analysis and a summary of the experiments from the literature were used to achieve this. The results of the theoretical, experimental, and finite element calculations were compared. Additionally, the significant variables were analyzed statistically, and an effective formula for calculating rectangular sections' torsional strength was created. The calculated potency was contrasted with the limited element findings and the experimental data of 76 reinforced concrete beams that were accessible in the literature in order to verify the formula's accuracy. It was discovered that the newly proposed prediction equation and the finite element approach may be utilized to predict the cracking and the maximum torsion capacity of concrete with normal, medium, and high strengths.

IK Fang, JK Shiau - Structural Journal, 2004 [11] The torsional strength, and deformation experimental findings for beams made of concrete with standard as well as high capacities (both NSC and HSC, as well) are provided. Purely torsion testing was performed on eight NSC (F'c = thirty-five MPa) and eight HSC (F'c = seventy MPa) beams with 350 * 500-millimeter cross-sectional and varying degrees of torsional reinforcement. The HSC beams outperformed the NSC beams that are similarly reinforced in terms of strength at the torso and cracking rigidity, according to test data. For higher reinforcement levels, HSC beams showed a comparatively sharper strength loss than NSC beams after reaching their peak strength. The greatest power of the experiment was nearly it was found to be 1.1 times larger. Working with the ACI 318-02 Codes design specification. The position of the compression diagonals was unaffected by the concrete's compressive strength. For the same applied torque, the primary strains of tensile in HSC beams were less than those in NSC beams.

Wen-Tang Young, Jyh-Kun Shiau, I-Kuang Fang, and Hao-Jan Chiu 2007 [12] Thirteen full-size normal-strength (NSC) and strong (HSC) Not much torsional reinforcement in beams of concrete were the subject of an experimental study. Results of the trials are discussed, including the torsional power, maximum fracture widths at the service loading level, crack patterns, torsional ductility, and post-cracking reserve strength. The cross-sectional aspect ratio, the compressive strength of the concrete, and the volume ratio of the twisting reinforcements are the main determining factors. It was discovered that the ratio of the transversal to the longitudinally reinforcement, in addition to the overall amounts of twisting reinforcement, reinforcing factors largely determines the post-cracking reserve strength's sufficiency for specimens having comparatively modest levels of supporting the torso. Based on our testing results for both HSC and NSC beams, the minimal torsional reinforcement requirements for NSC beams that have been suggested by other studies are also discussed.

FA Bernardo, SMR Lopes - Engineering structures, 2013 [13] The following work presents an investigation into the twist capacity and plasticity in the hollow beams made of high-strength concrete (HSC) subjected to just torsion. The plastic analysis is carried out using the outcomes of sixteen tested beams. A trend parameter made of plastic (PTP) was used to investigate the beams' plastic twist-holding capacity. The test beams' overall twist curves (versus) the plastic local twisting were used to define this parameter. It was demonstrated that PTP is a useful metric for capturing the experimental capacity of the beams to twist under test. For PTP study reveals a relatively limited amount of plasticity in conduct in hollow (HSC) beams in torsion. Additionally, concrete's compressive strength as well as the torsional reinforcement were considered the ratio of the torsion reinforcing. It is demonstrated that PTP appears to somewhat decline with increasing concrete strength. Additionally, it is demonstrated that there is a significant decrease in PTP as The ratio of torsional reinforcing increases additionally, that 1.30% is the maximum at which some plastic twist capacity may be guaranteed. Several significant codes, including American, Canadian, and European ones, are examined in relation to the capacity for plastic twisting noted regarding the examined beams. Well, it is demonstrated that by enforcing a top and a bottom number In terms of the ratio of reinforcement, the real American code is highest suitable.

Raid I. Khalel-2013 [14] Modern techniques for designing reinforced concrete beams torsional stresses typically employ A Space Bridge Comparison rather than the more classic skewed bending concept. This article examines a total of thirty-four (34) HSC stands for strong concrete. Rectangular beams that collapsed under complete twisting. These were extracted from published works. Two typical equations to forecast the twisting resisting instant TR plus the breaking twisting instant Tcr were obtained by doing regression analysis on the data. In contrast, the following equation is founded on seven fundamental principles elements, including the measurement of the effect of both lateral and axial reinforcements, the first equation is based on four major parameters, including sectional dimensions and concrete compressive strength f'c. Upon applying the ACI 413M-50 Code design equation, the test-to-calculated twisting ratios strength (Tutest / Tr-calc.) yielded a 3.23 % factor of variance when an ACI 413M-50 Code design equation was used; however, the suggested equation produced a COV of.

Asst.Prof Dr.Waleed_Awad_Waryosh, Lecturer Dr. Hadi_Naser Al-Maliki, Enas. Mabrok, Munaa- M.Sc. Student, 2015 [15] The purpose of this research is to look into the actions of empty beams made of reinforced concrete under torsion loads. Eight rectangular reinforced concrete beams with identical reinforcing ratios and dimensions (length 2000 x height 240 x width 170 mm) were investigated as part of the experimental study and Torsion testing was performed. Two rays portions are offered: a strong section and an empty section that fluctuates in proportion to its total slice surface and shape (18%, 18%, and 27%, respectively). Variables taken into account in the test program include the kind of concrete (normal and high strength) and the impact of the hollow shape and area. The test results the dynamics of Torque development and rays extensions, hollow core performance & impact on breakdown mechanisms, maximum torque levels, and breaking stress were all analyzed. According to test data, the final void part torque is roughly 89% for round voids with an eighteen percent hollow ratio, for rectangle empty, with eighty-three percent ± sixty percent sections (twenty-seven percent and eighteen percent of a rigid ray, respectively. The ultimate torque was seen to have increased by approximately 63%, 60%, and a circle, sixty-two percent (eighteen ration), rectangle (eighteen ration), and rectangle (twenty-seven percent proportion) shapes, correspondingly. The high-strength concrete type in solid beam increased the ultimate torque and cracking by approximately 100% and 66%, respectively.

C Joh. I Kwahk. J Lee. IH Yang. BS Kim, Advances in Civil. 2019 [16] Because of these members' lightweight and slenderness as well as the more straightforward way in which their reinforcement is arranged, there is a growing trend in reinforced concrete structures to use stronger concrete and steel. However, it is still necessary to check for any reduction in ductility that may arise from this increase in strength. This study aims to analyze the requirements connected considering a twisting least percent of reinforcement in light in the lowest ductile criterion, having an emphasis on Euro code II, taking into mind that this also concerns torque is designed. In order to look inside the ultimate appropriateness of the minimum torque support, the relationship In a bar supported with the smallest twisting reinforcing percentage, a connection to the twisting breaking stress & its ductility response is investigated.

Enas Al_Faqra، Yasmin Murad، Mu'tasim Abdel Jaber، Nasim Shatarat، 2020 [17] This study uses experimental methods to examine the twisting characteristics of high-strength continuously spiraling constructed out of concrete reinforcing placed transversely. Based on their concrete strength, the seventeen examples are grouped into four categories: 25-50-60-70 MPa. For each group, 2 different forms on the lateral Stirrups with helical with sealed reinforcing are employed at lateral spacing between seventy-five & twelve hundred millimeters. This ACI equation's projected values for analysis are compared to the test findings. According to test results, specimens manufactured with high-strength concrete had a higher maximum twisting strength compared to samples created using moderately robust concrete. The proportion of enhancement varies between 1.4% and 46.3%. Furthermore, findings indicate that specimens' ultimate torsional capability has increased. When comparing specimens manufactured with traditional closed stirrups to those reinforced using spiral reinforcement, the results indicate a greater final torsional capability for the former. The rise in the rate ranges from eight to thirty-four percent. According to The research's findings, high-strength concrete with Concrete with conventional sealed stirrups of identical toughness could display a lower maximum twisted storage capacity as concrete having continuously helical reinforcing. Additionally, is demonstrated that in this particular instance, using ACI-318 M-19 twisting formulas was adequate & safe.

JY Lee, M Haroon, DI Shin, SW Kim - Journal of Structural, 2021, [18] The subject matter restrictions The highest strength of yield associated with twisting & shearing is similar. Since the design processes in RC members' shear and twisting are comparable. The top and bottom limits, however, vary between codes. For instance, some standards set a maximum yield strength of 420–800 MPa for torsional and shear reinforcement. The experimental results of 42 members who were subjected to torsion and 73 members who were tested using strong reinforcing in shearing are presented throughout this work. The examination findings were thoroughly examined to learn more about the shearing and twisting actions of RC components fabricated of strong steel, together with other experiments from the literature. The test findings showed that regardless of maximum stress level, the crack width had been lower compared to the permissible regardless of the maximum is 0.41 millimeters when participants were strengthened to an ultimate yielding strength of 700 MPa. Shear tension failure occurred within the sheared members, including the load capacity of the stirrups approaching 600 Mega Pascal's, before the concrete web was crushed. But in the event of torsion, where the breaking point of the reinforcing exceeded 420 MPa, 18% of the 153 examples with failures due to twisting compressing. It is recommended to stick with the currently code-specified highest yielding limitation of 420 MPa for twisting design once sufficient test data is obtained to raise this ceiling. A limitation of approximately 600 MPa for the maximum yield strength of shear reinforcement is suggested in this study based on these assessments of data from tests.

Conclusions:

This paper drawn from a thorough analysis concerning the twisting behavior of beams made of concrete with good performance involves synthesizing findings from various studies, experimental tests, and theoretical analyses. Here are some key conclusions that might emerge from such a review:

1. Enhanced Strength: High-performance concrete's superior torsional strength arises from advanced material properties like higher compressive strength and improved durability.

2. Material Influence: Aggregate type, mix design, and reinforcement significantly affect HPC beams' torsional response, demanding a nuanced understanding of optimized performance.
3. Complex Behavior: Torsional behavior interacts with shear and flexure, requiring comprehensive consideration of multiple failure modes for accurate predictions.
4. Reinforcement Impact: Various techniques, including stirrups and fiber reinforcement, are vital in enhancing torsional capacity and ductility, crucial for minimizing cracking.
5. Refined Design Needs: Specific guidelines tailored for HPC beams under torsion might be necessary as existing standards might not fully capture their unique strength aspects.
6. Model Validation: Analytical models predicting HPC beam torsional behavior need refinement and validation against experimental data for practical accuracy.
7. Non-Destructive Assessment: Utilizing non-destructive methods like acoustic emission testing can provide valuable insights into torsional behavior without causing damage.
8. Construction Implications: Emphasizing practical implications, optimized designs, methodologies, and quality control measures are crucial for maximizing HPC beams' torsional performance.

Overall the evaluation's conclusions would likely emphasize the multifaceted nature of torsional behavior in high-performance concrete beams and advocate for a holistic approach considering material properties, design methodologies, reinforcement strategies, and the need for further research to advance the understanding and utilization of HPC in structural applications.

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