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厦门大学

硕 士 学 位 论 文

钢筋锈蚀的空间分布对梁受剪性能的影响

---基于数值模拟的研究

Influence of Spatial Reinforcement Corrosion on Shear Performance of RC Beams

---Based on a Numerical Investigation

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摘要

钢筋混凝土（以下简称 RC）结构的耐久性近年来逐渐成为国内外广泛关注的问题。其中，钢筋锈蚀是影响 RC 结构耐久性的重要因素之一。然而，以往大部分研究多是针对受弯性能，而对于受剪性能的关注较少。但在海洋氯化物环境下，由于箍筋相对截面较小且易受氯离子侵蚀，箍筋的锈蚀程度较纵向受拉钢筋严重，有可能发生脆性的受剪破坏先于受弯破坏的预期外现象。再者，大部分的研究多是考虑钢筋整体均匀锈蚀对结构性能的影响，但这与实际结构中混凝土内部的钢筋锈蚀多呈非均匀、非对称的空间分布不符。

数值模拟是一种非常有效的研究方法，其既可以观察到宏观力学现象，又可以收集实验无法测定的微观情报。本文在本课题组实验的基础上，使用有限元软件 Diana，对钢筋锈蚀的空间分布对 RC 梁抗剪性能的影响展开以下研究：1）纵向受拉钢筋的整体锈蚀对剪跨比不同无腹筋梁抗剪性能的研究；2）纵向受拉钢筋的局部粘结退化对有腹筋梁抗剪性能的影响；3）箍筋的整体锈蚀以及箍筋的局部锚固失效对有腹筋梁抗剪性能的影响。数值模拟较好地符合了实验结果，并得到了以下一些有益结论：

（1）对于无腹筋长梁，纵向受拉钢筋锈蚀导致的粘结退化引起“拉拱机制”增强，提高了受剪承载力。对于无腹筋短梁，粘结退化对承载机制的影响并不明显。

（2）理论分析证明无腹筋梁受剪断裂能与“剪切应力保持系数-切应变曲线”包络面积的平方成正比。数值模拟和实验的相互验证结果表明，“剪切应力保持系数-切应变相关关系”曲线的包络面积随着剪跨比增大而减小，证明受剪断裂能随剪跨比的增加呈减小趋势，这和实验现象以及以往的研究相符。

（3）相比于纵向受拉钢筋跨中粘结退化对有腹筋梁的影响，端部粘结退化更为危险。端部粘结退化会导致梁刚度和承载力大幅下降，且最终破坏呈脆性。

（4）箍筋整体锈蚀对于有腹筋梁的抗剪承载机制的影响较小，并不会引起承载机制的迁移，但箍筋锈蚀导致的断面减小将降低整体抗剪承载力。

（5）从假定锈蚀箍筋局部锚固失效现象，进行多种情况的箍筋锚固失效的数值模拟得出的结果显示，局部锚固失效降低了梁的承载力和刚度，但降低幅度受局部锚固失效位置的影响；靠近支座处箍筋下端锚固失效+靠近加载点箍筋上端锚固失效导致抗剪承载力下降最大；靠近支座处箍筋上端锚固失效的影响较小；剪跨区内箍筋上端全部锚固失效或下端全部锚固失效对抗剪性能的影响介于以上两者之间。上述结果还受梁尺寸的影响，在箍筋的锚固失效位置分布相同的情况下，大尺寸梁的抗剪承载力下降程度相对较低。

关键词：RC 梁 数值模拟 抗剪承载机制 钢筋空间锈蚀 箍筋锚固失效

Abstract

The durability of reinforced concrete (RC) structure has become a problem being widely concerned at home and abroad in recent years. Reinforcement corrosion is an important factor affecting the durability of RC structure. Most of the publised researches on the influence of reinforcement corrosion on the structural performance of RC beams focused on flexural performance, but few of them focused on shear performance. Under marine environment subjected to chloride ingression, the corrosion degree of stirrups is more serious than longitudinal reinforcements because stirrups have smaller section and would be eroded by chloride more easily. As a result, brittle shear failure would happen rather than flexural failure during there sevice life. Furthermore, most of the publised researches focused on the effect of uniform corrosion on the structral performance of RC members, but in fact, if the corrosion level of steel bars develop to such a lever that coule affect the structural performance of RC members, the corrosion state is always not uniform, it exhibits nonuniform and asymmetric with spatial distribution.

Numerical simulation is a very useful method of studying the durability of RC structures. Through this method, we can not only observe macro mechanics phenomenon but also acquire some micro information which cannot be obtained by experimental investigations.

Based on the test results of our research team, numerial investigation using commercial FEM software Diana was used to carry out an investigation on the influence of spatial reinforcement corrosion on shear performance of RC beams, which includes the following: 1) The influence of the uniform corrosion of longitudinal tension bars on the shear performance of RC beams; 2) The influence of the local unbond area of longitudinal tension bars on the shear performance of RC beams; 3) The influence of the uniform corrosion and local anchorage failure of

stirrups on the shear performance of RC beams

Numerical simulation results agreed well with the experimental results and within the scope of this study, the following conclusions can be drown:

1. For beams with long shear span, the bond deterioration resulted from longitudinal tension bar corrosion caused a buildup of tie-arch mechanism, leading to an increase in shear capacity, while for beams with short span, the bond deterioration had less influence on RC performance.

2. Theoretical analysis showed that, shear fracture energy is in direct proportion to the envelope area of the $\beta-\gamma$ curve. By comparason and check of the analytical output and test results, it conclude that the envelope area of the $\beta-\gamma$ curve would decrease with the increase of shear-span-to effective ratio, which agreed well with the conclusions by published researches.

3. Compared with the bond deterioration area in the vicinity of middle portions, the area near the supporting position to more dangerous for RC beams, it might cause significant decrease in stiffness and shear capacity of RC beams.

4. Stirrup corrosion had less effect on load-carrying mechanism of RC beams, load-carrying mechanism transition did not happen in the specimens containing corroded stirrups, but the shear capacity of RC beams decrease with the increase of corrosion level of stirrups.

5. The results of numerical simulation aimed to investigate the different local anchorage failure of stirrups on the shear performance of RC beams shows that : Local anchorage failure of stirrups would caused the decrease of stiffness and the shear capacity of RC beams; Anchorage failure occured both on the bottom side of the stirrups placed near the supporting position and on the top side of the stirrups placed near the loading position would cause the most dramatic decrease of shear strength of RC bemas;Anchorage failure occured on the top side of the stirrups place near the supporting position or on the bottom side of the stirrups placed near the loading position would has the smallest influence on shear strength; The influence of the

anchorage failure occured on the top side or bottom side of all stirrups within the shear span were in between.The above results are affected by the size of RC beams, and in the large-sized beams, the reduction of shear capacity caused by the same local anchorage failure was less that that is the case of small-sized beams.

Key Words： RC beam; numerical simulation; shear performance; spatial reinforcement corrosion; stirrup anchorage failure

目录

Contents