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論文内容の要旨（博士）

博士学位論文名	円形鋼管構造部材に対する接着接合を応用した耐震補強工法に関する研究
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（要旨 1,200 字程度）

既存鉄骨造建築物の耐震改修工事では、既存鉄骨と耐震補強部材の接合方法として現場溶接が広く用いられている。しかし、現場溶接は、円形鋼管部材のように板厚の薄い部材では品質管理が難しく、工場や物流倉庫のように火気使用が制限される建物では適用が困難であることが課題として挙げられる。これらの課題に対して、エポキシ樹脂を用いた接合方法に関する多くの研究が進められており、純粋なせん断力に対して高い接着せん断強度を発揮する一方で、剥離力が作用すると接着せん断強度が低下することが明らかになっている。また、既往の研究は平板同士の接着を対象としたものがほとんどで、円形鋼管部材を対象とした研究は少なく、十分な知見が蓄積されているとは言い難い。そこで、本研究では、既存円形鋼管部材を対象として、エポキシ樹脂による接着接合と支圧による応力伝達機構を有する無溶接接合工法を提案し、耐震補強部材として鉄骨枠付きブレースを想定した際の接合部の力学的特性を把握するとともに、接合部形状や既存鋼管径がその特性に及ぼす影響を確認することを目的とした。また、本接合工法の接着接合部の耐力評価式を提案すること、有限要素法解析により耐力評価式の妥当性の確認および接着接合部の応力状態を明らかにすることを目的とした。 3章では、接着接合部の接着性能試験を行い、載荷範囲、接着長さ、既存円形鋼管部材板厚が接着せん断強度に及ぼす影響を確認した。試験の結果、載荷範囲を既存円形鋼管部材円周方向の半周としたときの最大荷重は、全周載荷時の約50%に低下し、接着面の円周方向の応力分布が一様ではないことが明らかとなった。また、接着長さの増加に伴い接着せん断強度が低下すること、既存円形鋼管部材の板厚が接着せん断強度に及ぼす影響が小さいことを明らかにした。 4章では、接合部試験により既存鋼管径や接合部形状が力学的特性に及ぼす影響を検証した。試験の結果、本接合工法の破壊は接着接合部の既存鋼管接着部エポキシ樹脂または金物継ぎ目位置のエポキシ樹脂の破壊となること、本接合部に生じる曲げモーメントの増加が接合部耐力に及ぼす影響が小さいこと、接着接合部金物継ぎ目の開き止めが接合部耐力を向上させることを明らかにした。また、本接合部付近の既存円形鋼管部材に曲げ降伏が生じることで、既存鋼管接着部のエポキシ樹脂が早期に破壊する可能性が推察された。 5章では、試験結果を基に仮定条件を定め、接着接合部の応力を推定することで接着接合部の耐力評価式を提案した。耐力評価式は、既存鋼管接着面破壊時の耐力と金物継ぎ目位置破壊時の耐力を考慮し、試験結果に対して安全率1.30以上を有する。また、本接合工法の設計の考え方を示した。 6章では、接着性能試験および接合部試験について有限要素法解析による検証を実施した。接合部試験の解析から接着接合部に作用する力の範囲を明らかにし、提案式で定めた仮定条件が妥当であることを確認した。接着性能試験の解析結果から既存鋼管接着面のエポキシ樹脂破壊時の主応力を推定し、接合部試験時の接着接合部の破壊形式を明らかにした。また、それぞれの試験で接着面に生じる応力分布を明らかにした。 7章では、本研究で得られた知見と今後の課題を示した。

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Abstract (Doctor)

Title of Thesis	Study on Seismic Retrofit Method for Steel Pipe Members by Adhesively Bonding
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Approx. 800 words

In the seismic retrofitting of existing steel-frame buildings, field welding has been widely employed for joining existing steel members to seismic reinforcement members. However, field welding presents several practical challenges. Ensuring adequate quality control is difficult for thin-walled components such as steel pipe members. Furthermore, this method is not readily applicable in buildings where welding is restricted, such as factories and distribution warehouses. To address these issues, numerous studies have been conducted on bonding methods using epoxy resins. Although epoxy resins exhibit high shear bond strength under pure shear loading, their strength decreases when peel forces are introduced. Most previous studies have focused on the bonding of flat plates, and only limited research has been conducted on steel pipe members. Therefore, sufficient knowledge in this area has not yet been established. Based on these backgrounds, this study proposes a non-welded joint method for existing steel pipe members that uses epoxy resin bonding and a bearing-based stress transfer mechanism. The proposed joint method is intended for application to braced steel frames used as seismic reinforcement members. The objectives of this study are to clarify the mechanical characteristics of the proposed joint method, to investigate the effects of joint configuration and existing steel pipe diameter, to propose a capacity evaluation formula for bonded joints, and to verify the validity of the proposed formula through finite element analysis while also clarifying the stress state in the bonded joints.

In Chapter 3, bonding performance tests were conducted on bonded joints to investigate the effects of loading range, bonded length, and the thickness of the existing steel pipe members on shear bond strength. The test results demonstrated that when the loading area was limited to half of the circumference of the existing steel pipe member, the ultimate load decreased to approximately 50% of that under full-circumference loading, indicating that the circumferential stress distribution on the bonded surface was non-uniform. In addition, the results showed that the shear bond strength decreased with increasing bonded length, whereas the thickness of the existing steel pipe members had little influence on the shear bond strength.

In Chapter 4, the effects of existing steel pipe diameter and joint configuration on the mechanical characteristics were examined through joint tests. The test results demonstrated that failure in the proposed joint method occurred either in the epoxy resin at the existing steel pipe joint or in the epoxy resin at the metal joint, that an increase in the bending moment generated at the joint had a negligible influence on the joint capacity, and that preventing the metal joint from opening enhanced the joint capacity. Furthermore, it was inferred that the bending yield of the existing steel pipe members in the vicinity of the joint could induce premature failure of the epoxy resin at the bonded surfaces of the existing steel pipe.

In Chapter 5, a capacity evaluation equation for bonded joints was proposed based on assumptions informed by test results and estimates of the stresses acting in the bonded joints. The proposed capacity evaluation formula considered both the failure load at the bonded surfaces of the existing steel pipe and the failure load at the metal joint, and the test

results had a safety factor of 1.30 or greater. In addition, the design philosophy of the proposed joint method was presented.

In Chapter 6, the results of the bonding performance and joint tests were verified using finite element analysis. Analysis of the joint tests clarified the range of forces acting on the bonded joints and confirmed the validity of the assumptions adopted in the proposed equations. Based on the analytical results of the bonding performance tests, the principal stresses at epoxy resin failure points on the bonded surfaces of the existing steel pipes were estimated, and the failure modes of the bonded joints observed during the joint tests were identified. In addition, the stress distributions arising at the bonded surfaces in each test were clarified.

Chapter 7 summarizes the findings of this study and identifies issues to be addressed in future research.