様式例：課程博士用

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論　文　要　旨(博士)

論文題目	グリッドシステムを援用した殻構造物の非線形挙動解析に関する研究

（要旨 1,200字程度）

柱の無い広い空間を形成する大空間構造物や殻構造物に対しては，鋼部材を組合せたラチス殻構造物や鉄筋コンクリート殻構造物が適用されることが多い。これらの構造物には，耐震性能，耐風性能の確保，使用上の要求など様々な条件を満足させることが要求される。このような構造物の設計において，構造物の特性を把握することが重要となるが，対象となる構造物が非常に大型となるため，実験によって検証を行うことが困難であり，数値解析で検討がなされることが殆どである。そのため，構造解析については，(1)より実際の非線形挙動を表現することができる解析手法，(2)短時間で設計者が的確に判断を行うための資料を得ることのできる解析手法が必要となる。

本論文では，(1) 構造設計における膨大でパラメトリックな非線形解析を効率的に実施しうる計算環境の必要性に応ずるため，既存のマイクロコンピュータを連動させて，これを効率的に処理するグリッドシステムの手法を導入する。(2) このグリッドシステムの構造解析への有効性を検証するために，空間構造物の一種である体育館，鉄塔を例題として非線形解析を実施する。併せて，これらの構造物のパラメトリックな地震応答解析を通して，その非線形挙動を分析し，耐震設計上の問題を明らかにし，設計法について提案する。現在大規模な鋼構造物の基本的な問題である地震応答性状の分析に焦点を合わせ，(3) 地震活動度の高い地域における冷却塔としての鉄骨造網目殻構造物を取上げ，その非線形挙動に関してグリッドシステムを援用してパラメトリックに解析し，その実現性を検討する。(4)続いて，繰返し荷重に対する劣化性状の分析が必要とされている大規模 RC 造殻構造物として RC 造冷却塔を，また最近再び注目を集めつつある屋根型殻構造物として逆傘型 HP 屋根を取上げ，それぞれを非線形解析によってその挙動を分析し，支持方法，配筋方法などを検討する。

第 1 章では，序論として，本論文の背景と目的，各章の構成を述べる。

第 2 章では，グリッドコンピューティングシステムに関する説明と，グリッドコンピューティングシステムを用いて設計変数の範囲内での全ての組合せに対する解析を行うことで，構造設計における各種の設計変数の影響や条件を満足する最適解の範囲を示す方法の有用性に関して検討を行う。

第 3 章では，鋼製冷却塔を対象として，非線形解析を行い，弾塑性性状の分析と，各種の設計変数が全体の挙動に及ぼす影響について分析を行う。

第 4 章では，RC 造冷却塔と，逆傘型 HP シェルを対象として，放射環状型格子モデルを用いた RC シェルの解析手法と，グリッドシステムを用いることで，RC 造シェル構造物の繰返し荷重下における弾塑性性状の分析と，各種の設計変数が全体の挙動に及ぼす影響について分析を行う。

第 5 章では，総括として本論文によって得られた結果を示し，今後の課題について提起する。

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論　文　要　旨(博士)

論文題目	A Study for Analysis of Nonlinear Behavior of Shell Structures Using Grid System

（要旨 1,200字程度）

Shell structures in civil engineering fields are commonly applied to space structures, industrial structures and similar structures which cover large area without columns inside, for example, as cooling towers of reinforced concrete and sport halls of steel material. These structures are designed for severe loading conditions, and are often implemented with hysteretic dampers or seismic devices and pre-stressing for upgrading their load bearing capacities against earthquakes and strong winds. In design of these space structures, nonlinear responses are required for accurate understanding their nonlinear behaviors. However, it is almost impossible to analyze their characteristics with experiments because of large scale of the structures. Therefore, a nonlinear numerical analysis is considered more effective and often applied in design analysis. In such cases, appropriate analysis methods which are able to simulate the nonlinear behaviors are indispensable to provide data as much as possible for understanding from many aspects, followed by a necessity to perform parametric nonlinear analyses considering many important structural factors.

The objectives of the present study are described as follows; (1) to propose a high performance computing system for an efficient nonlinear structural analysis by implementing a computer processing based on the grid system composed of a dozens of personal computers, (2) to investigate and prove the efficiency of this system by applying it to analysis of structures for optimum design and nonlinear analysis covering many structural and loading parameters, (3) to discuss, by applying the computing system for parametric analyses and based on the results, and to propose possibility of steel lattice cooling tower at regions of high seismic risk, and also (4) by applying the computing system to discuss the nonlinear behavior under cyclic loading for RC cooling towers which are now urgently required some studies about structural deterioration under cyclic loadings due to wind loads, and to investigate the nonlinear behavior of RC hyperbolic parabolic inverted umbrella shells as a typical example for roof shell structures which recently attracts an attention from architects.

The contents of each chapter in this thesis are summarized as follows.
In the first chapter, the background and objectives of this study are presented.
In the second chapter, the concept and grid computing system for structural analysis are proposed, and the concept and applicability of the grid system are discussed for showing the efficiency for structural optimization and studies covering many parameters. In this discussion, the grid system is applied to parametric analyses of a sport hall and a tower with various structural parameters, followed by a proof that this system is able to perform a lot of structural analyses in a moderately short time, and that the structural characteristics can be investigated based on the analyses to investigate the effects of those many parameters over wide ranges, otherwise a lot of cases of calculation would not be possible and a large computational times were needed. As for the sport hall, a simplified model is proposed for a medium-scale hall and a set of design charts are provide for selecting a set of an appropriate parameter of roof brace and gable brace. As for the tower, a steel transmission tower for power plants, to be retrofitted using a TMD, is discussed for find an optimal set of structural parameters for TMD giving an appropriate spring constant and a damping coefficient.
In the third chapter, this grid system is applied to a steel cooling tower implemented with buckling restrained braces for columns at a base. Based a set of parametric analyses for the cooling tower under severe earthquake motions, the possibility of steel lattice cooling tower is discussed for regions of high seismic risks such as India, China and Turkey, and an optimal size of buckling restrained braces which should be installed at the lower part of the steel cooling tower is investigated.
In the fourth chapter, a RC cooling tower and a RC HP umbrella shell are studied based on shell FEM considering many structural parameters, using the present efficient grid system, based on a constitutive equation due to Lattice model for concrete. Based on the results, several discussions and findings are presented as follows. First, as for the elasto-plastic nonlinear behavior of the RC cooling tower supported at the lower lintel by columns, the importance of the effects of cracking, tension stiffening and deterioration of concrete elements under cyclic loads is clearly described, and an important suggestion is drawn for structural design to give a conclusion that the effects of cyclic wind loads can not be negligible in assessing the stiffness and ultimate strength of the RC cooling towers. Second, as for the elasto-plastic nonlinear behavior of the RC HP umbrella shell under a self weight and pre-stresses, the effect of material nonlinearity of concrete and pre-stress is studied and discussed under vertical loads, proportional to self weight, followed by a conclusion that the deterioration of the concrete under cyclic loads is considerably important in assessing the structural performance of the RC shell structure especially for the ultimate state and the deterioration of stiffness under cyclic loading.
In the final chapter, the total conclusion of this present thesis is described.