学位論文

しらす地山における山岳トンネルの設計・施工法に関する研究

Studies on Design and Performance of Tunnel in Shirasu Ground

多宝　徹 Toru TAHO [*1]

要　旨

トンネルを構築するための有力な手法のひとつである山岳工法は，山岳地帯の地山を対象に発達してきたものであり，掘削対象地山は，主に岩盤である。一方で，南九州には，“しらす”と呼ばれる更新世後期の火砕流堆積物の未固結部が広く分布し，台地を形成している。しらすのような大深度の未固結地山の存在は少ないことから，同様な地質へ山岳工法が適用された事例も少なく，しらす地山におけるトンネルにおいても，その設計・施工法が確立されていないのが現状である。このようなことから，本研究は，しらす地山におけるトンネルの挙動を力学的に解明し，設計・施工を合理的に進めるための根拠を得ることを目的として実施したものである。

第1章では，しらす地山における山岳工法トンネルの研究実績，設計・施工の現状についてまとめた上で，本研究の目的とその必要性を示した。

第2章では，本論文で用いる“しらす”の定義を明確化し，トンネル掘削対象地山としてしらす地山を分類する際に，有効と判断される指標を示した。

第3章では，文献を通じて，しらす地山のトンネルの実績を整理し，第4章では，実際にトンネル掘削を行った鹿児島市に位置するトンネルの掘削時の情報をまとめ，考察を加えた。

第5章では，トンネルの施工情報，原位置試験，室内試験の結果から，しらす地山においては，地山の一軸圧縮強度が地山の初期応力に比べて著しく小さいことから，掘削等による応力解放に伴い，強度や変形係数の低下が顕著に現れることを確認した。その上で，しらす地山の力学的挙動を適切に把握するためには，応力解放の影響を考慮することが極めて重要であることを示した。

第6章で，応力解放による変形係数の変化に着目した数値解析モデル（応力依存剛性変化モデル）を構築し，第7章で，しらす地山における通常断面のトンネルに本モデルを適用し，従来の弾性解析や非線形解析では表現できなかったしらす地山のトンネルの独特な挙動を表現した。さらに，第8章では，応力依存剛性変化モデルを複雑な加背の超大断面トンネルに適用し，解析モデルのしらす地山における汎用性を確認するとともに，特殊条件下でのしらす地山のトンネルの力学挙動を解明した。

最後に，第9章で，前章までの研究結果をまとめ，しらす地山における山岳トンネルの合理的な設計・施工法を提案した。

キーワード：山岳トンネル，しらす，未固結土，超大断面トンネル，三次元数値解析，応力依存剛性変化モデル

Summary

The main purpose of this thesis is to establish a rational tunneling method in Shirasu ground.

Shirasu, which is defined as the non-welded part of pyroclastic flow deposits, is widely distributed in the southern part of Kyushu Island. Shirasu is regarded as soft ground when the mountain tunneling method is applied because its unconfined compression strength is 20-100 kN/m^2. Nevertheless, it is well known that Shirasu tunnels are comparatively stable. However, the stability mechanism has not been clarified, and rational tunneling methods in Shirasu ground are therefore not clear, either. In order to clarify this problem, these studies were executed.

The following are summaries of each chapter.

Chapter 1 as the introduction to these studies provides the background and briefly explains the purpose in order to clarify the significance of these studies.

Chapter 2 reconfirms definition of Shirasu, which has had various meanings, and gives it a new definition.

Chapter 3 describes the results of research of literature on past cases of constructing Shirasu tunnels.

In Chapter 4, the behavior under the excavated Shin-Takeoka Tunnel, which was constructed in Shirasu plateau, is analyzed.

Chapter 5 shows the deformation characteristics of Shirasu ground for tunneling.Primitive stress in

*1 九州支店

deep Shirasu ground is much larger than its unconfined compression strength, so when examination of the physical properties of Shirasu is performed, the influence of stress liberation has to be carefully considered. The modulus of deformation of Shirasu in elastic domain of stress-strain curve has remarkable stress dependency. Specifically, the modulus of deformation of Shirasu decreases as its confining pressure decreases.

Chapter 6 shows the construction process of the original nonlinear constitutive model by using FDM taking account of the geotechnical properties of Shirasu ground. The result of a numerical experiment shows the basic dynamic structure of the cutting faces of Shirasu ground tunnels, which has not been explained by former theories.

As the cutting face of the tunnel approaches an arbitrary point in deep ground, the confining pressure at this point gradually decreases. When the cutting face reaches it, its confining pressure decreases much more. Following decrease in the confining pressure, the modulus of deformation of Shirasu decreases, too. And the ground where the modulus deformation has decreased can no longer take large loads, and so major principal stress also decreases. This is why the cutting faces in Shirasu ground are relatively stable. But, in the case where the overburden of the tunnel is higher than 50 m, the decrease in major principal stress is not enough to keep the cutting face stable, and the ground ahead of the cutting face is loosened. On the other hand, the ground at the back of the tunnel supports being under a triaxial compression state by the internal pressure effect is comparatively stable, and the tunnel supports are also comparatively stable.

In Chapter 7, the original nonlinear constitutive model is applied to Shin-Takeoka Tunnel and the dynamic structure of Shirasu tunnels is clarified, by comparing the numerical results with the field measurement data.

In Chapter 8, the original nonlinear constitutive model is applied to an extremely large cross section of 378 m^2 in an excavation area and clarifies the dynamic structure of the extremely large section.

Chapter 9 proposes a rational design and performance method for tunnels in Shirasu ground based on the above studies, and also describes several attention points in constructing tunnels under special ground conditions.

Chapter 10 describes the research results on a rational tunneling method for Shirasu ground. In addition, future prospects are given.

［出典］多宝　徹：しらす地山における山岳トンネルの設計・施工法に関する研究，鹿児島大学大学院学位論文，2013. 3