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Geotechnical characterisation of fine-grained alluvial & proluvial soils for a motorway project in Kosovo

Caractérisation géotechnique des sols alluviaux et proluviaux à grain fin pour un projet d'autoroute au Kosovo

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ABSTRACT: Description and classification of fine-grained soils for large earthworks projects is extremely important to the success of the project, particularly for embankment construction. Establishing the correct profile of undrained shear strength and appropriate drained (effective stress) strength parameters is also critical in consideration of aspects of the project such as founding soils for embankments and stability analysis for deep cuttings. This paper discusses the investigation and characterisation of fine-grained alluvial and proluvial soils in the context of a large motorway scheme in Kosovo. The methodology of geological identification and geotechnical investigation of these soils is described and engineering parameters, including soil classifications, are presented.

RÉSUMÉ: La description et la classification des sols à grains fins pour les grands travaux de terrassement sont extrêmement importantes pour le succès du projet, en particulier pour la construction de remblais. L'établissement du profil correct de la résistance au cisaillement non drainé et des paramètres appropriés de résistance drainée (contrainte effective) est également essentiel compte tenu des aspects du projet tels que les sols de fondation pour les remblais et l'analyse de la stabilité pour les déblais profonds. Cet article traite de l'enquête et de la caractérisation des sols alluviaux et proluviaux à grain fin dans le contexte d'un vaste projet d'autoroute au Kosovo. La méthodologie d'identification géologique et d'investigation géotechnique de ces sols est décrite et les paramètres d'ingénierie, y compris la classification des sols, sont présentés.

Keywords: ground investigation; geotechnical parameters; alluvium; proluvium

1 INTRODUCTION

The Morine-Merdare (M9) Motorway comprises the construction of almost 90km of dual carriageway motorway in Kosovo. The data presented here is distilled from Sections 7, 8 & 9 of the project, a study area bounded by Prishtine to west, Fusche Kosove to the east, Kastrict to the north and Bernice E Poshtme and Lebane to the south. The topography of these sections of undulating ground within an intra-mountain valley. The proposed highway alignment consists of alternating cuts and fills. Cuttings are typically of the order of ~3m deep, with a maximum depth of ~9m. The majority of the alignment was constructed on embankment, typically of the order of 3 to 8m high. The maximum embankment height extends up to ~11m.

A substantial systematic ground investigation program was implemented in 2010-2011 in order to develop the geotechnical design methodology for the project. This consisted of mainly intrusive investigation techniques including rotary-bored boreholes with in situ field tests and cone penetration testing. A laboratory testing program was also implemented.

2 GEOLOGY & HYDROGEOLOGY

2.1 *Tertiary & Quarternary geology*

The Kosovo Basin is an intramontane depression which has been infilled with a succession of clays, silts, silty gravels and organic material in the form of coal and/or lignite layers. The depth of these infill materials are believed to be around 100m thick at the deepest, reducing to shallow depth as these materials lay up against the mountain ridges which form the eastern and western extents of the Kosovo Basin. Figure 1 shows a geological map of the Study Area with the proposed route alignments superimposed.

The natural soils in the majority of the study area are formed from proluvial and possibly deluvial debris generated from the surrounding mountain ranges. These strata are typically reasonably well graded by the action of water during deposition. The extent of each episode of deposition tends to be variable leading to interbedded layers of clays, silts and silty gravels, which tend to become finer in nature with distance from the source mountains. In general, these proluvial soils have been subject to significant compressive loading in their geological history and are consequently overconsolidated. The neogenic proluvial soils are partially overlain by quaternary alluvial soils, associated with the natural water courses which flow through the study area. These alluvial deposits are much younger in age than the proluvial materials and consequently are significantly softer than the proluvial deposits. The composition of the alluvial soils are similar to the proluvial soils i.e. clays, silts and silty gravels.

In the north and northwest of the study area higher river terrace deposits have been identified beyond the extents of the current alluvial channels. These features have likely arisen from the existing water courses, where the river water levels have been significantly higher in the geological past than they are at present. These river terrace deposits are typically well graded granular materials (sands and gravels) which have been washed of the finer materials (silts and clays) during the depositional process.

2.2 *Hydrogeology*

The Study Area lies within the catchment area of the Black Sea, which lies to the east of Kosovo. The principal direction of drainage of the major watercourses in the Study Area is to the north, with subsidiary watercourses generally flowing in east or westward directions, from the adjacent higher ground, to discharge into the major rivers. The principal watercourses within the Study Area are the Sitnica, Gracanica, Pristevka and Brnika Reka Rivers which are concentrated in the south and west of the Study Area. Anecdotal evidence of routine flooding of the Sitnica and Gracanica Rivers collected prior to the commencement of works for Sections 4 to 7 has been verified by observed flooding of these watercourses in the winter of 2010/2011.

Based on the large scale hydrogeological mapping and the descriptions of the soils and rock which have been recorded in the Study Area it is considered unlikely that any major aquifers are present within the Study Area. The hydrogeological mapping identifies the proluvial soils and rock exposures as medium to low permeability aquifers or aquicludes. However there is the potential for some of the more granular deposits, in particular the river terrace materials, to act as local water sources.

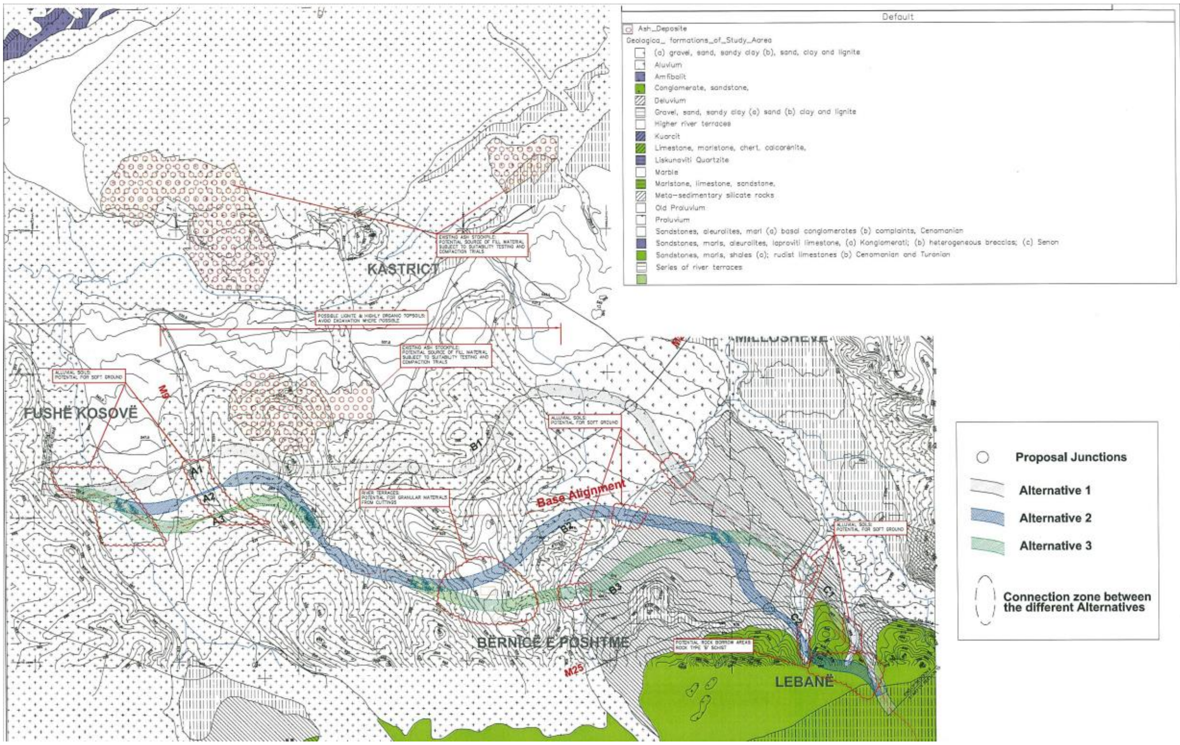

Figure 1. Geological mapping of Sections 8 & 9

3 GEOTECHNICAL CHARACTERISATION

3.1 Basic soil characterisation of alluvium and proluvium

Ground investigation in the Study Area was ongoing over the period 2009-2011. The primary investigative tool was conventional rotary coring used to obtain continuous cores of fine-grained soils for geotechnical description and field testing. The core barrel diameter typically used was 101mm (external) yielding 89mm diameter cores. A combination of bulk sampling and piston-less Shelby tubes were used for obtaining laboratory samples. Static cone penetration testing (CPT) was also undertaken to provide additional profiling and data.

Deposits of coarse and fine-grained soils were encountered to depths extending beyond 40m. From the desk study appraisal, these were categorised into four distinct units giving cognisance to the geological conditions anticipated from the desk study. These categories included:

- Fine-grained alluvial deposits (ALF)
- Coarse-grained alluvial deposits (ALC)
- Fine-grained proluvial deposits (PRF)
- Coarse-grained proluvial deposits (PRC)

The fine-grained deposits are the focus of this paper.

3.2 Stress history and OCR

The complex depositional environment of the intramontane valley makes it difficult to establish from first principles a reliable estimate of preconsolidation stress and hence overconsolidation ratio (OCR). Preconsolidation pressure was measured in the oedometer and an analysis of the cone penetration results following the correlations of Ladd & Foott (1974), normalised by Schmertmann (1975), based on the ratio of undrained shear strength to in situ vertical effective stress.

The resulting values of OCR for both the ALF and PRF soils are shown in Figure 2. The ALF is shown to be normally consolidated to lightly overconsolidated and, as expected, the PRF was considerably more overconsolidated than the ALF. The estimated OCR from oedometer testing of the PRF is also shown and these were found to corroborate the estimate from the CPT in a reasonable fashion.

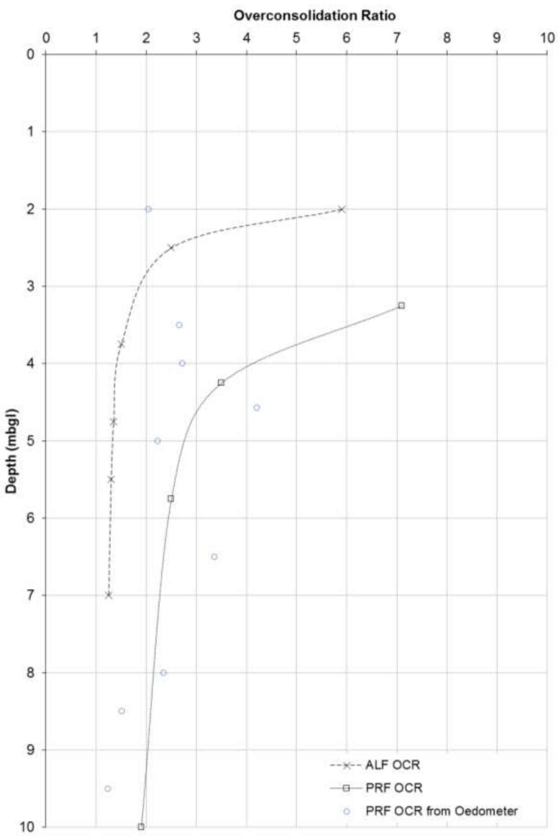

Figure 2. Estimate of overconsolidation ratio

3.3 Index properties

The ALF and PRF are typically described as firm to stiff gravelly silty CLAY frequently with calcareous concretions or shelly particles. The ALF is distinct from the PRF in terms of colour as shown in Figure 3 and Figure 4 for ALF and PRF respectively.

Index properties are comparable for ALF and PRF. As well as material colour, it is primarily measurements of natural moisture content which can be used to distinguish the units in terms of index properties though this subject to spatial and depth variation. Table 1 summarises basic index properties for the materials and Figure 5 shows a summary A-line plot of ALF and PRF units for comparison.

In terms of Atterberg limits, ALF and PRF classify as either clay of intermediate to high plasticity or silt of high to extremely high plasticity.

Figure 3. Core of ALF

Figure 4. Core of PRF

Soil Unit		ALF		PRF	
Index property	**Unit**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Natural moisture content	%	43.17	14.56	37.13	14.68
Bulk density	Mg/m^3	1.75	0.138	1.76	0.114
Dry density	Mg/m^3	1.26	0.209	1.29	0.169
Liquid limit	%	64.82	16.02	65.30	16.31
Plastic limit	%	35.61	8.23	34.93	8.72
Plasticity index	-	29.21	10.76	30.37	10.70

Table 1. Summary of index properties

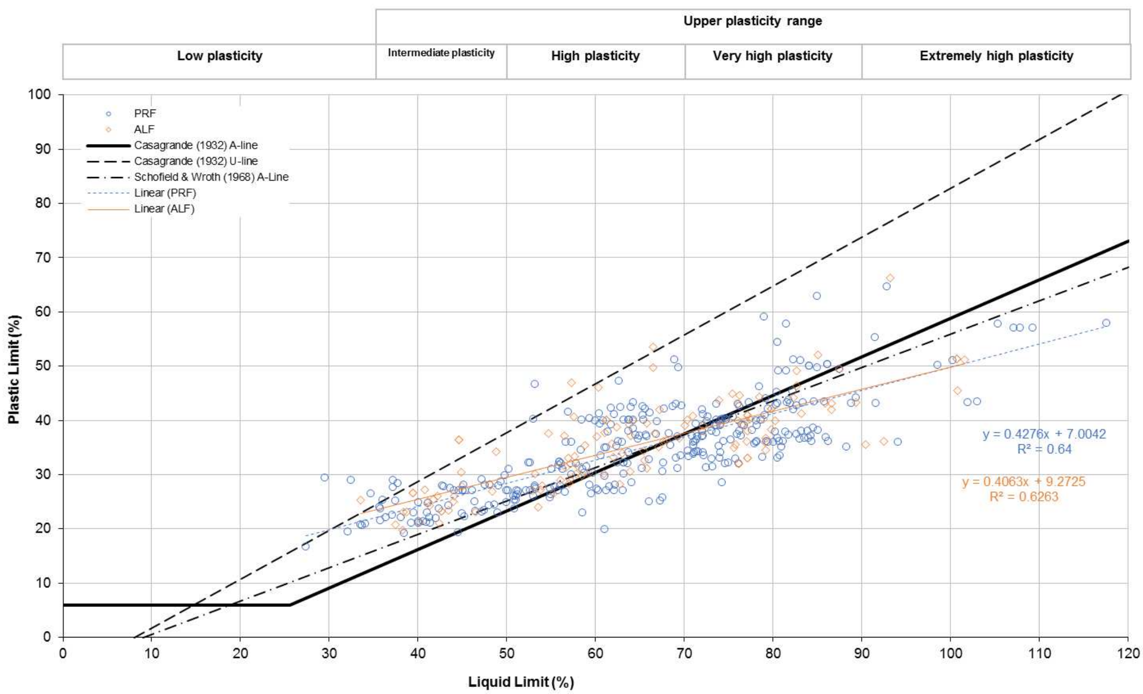

Figure 5. Summary A-line plot for ALF and PRF

3.4 Material grading

In terms of particle size distribution, the ALF and PRF classify as Class 2 materials in line with the UK Specification of Highways Works Volume 1 Series 600. Figures 6 & 7 show the particle size distributions for the ALF and PRF respectively. Both material types classify as Class 2A/B predominantly in terms of grading but with a reasonable proportion classifying as Class 2C. Of particular note is the wide range of fine material (silt and clay fractions) characterising the material. The average proportion of fine material (i.e. <0.063mm) is 48.0% and 55.5% for the ALF and PRF respectively.

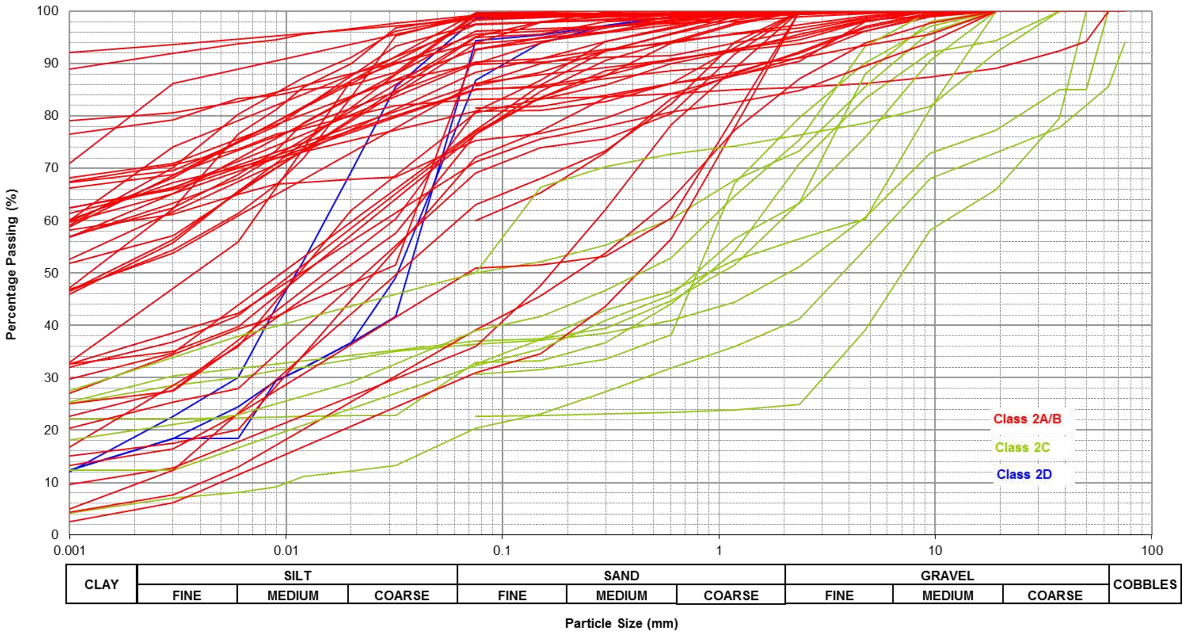

Figure 6. Particle size distributions for ALF

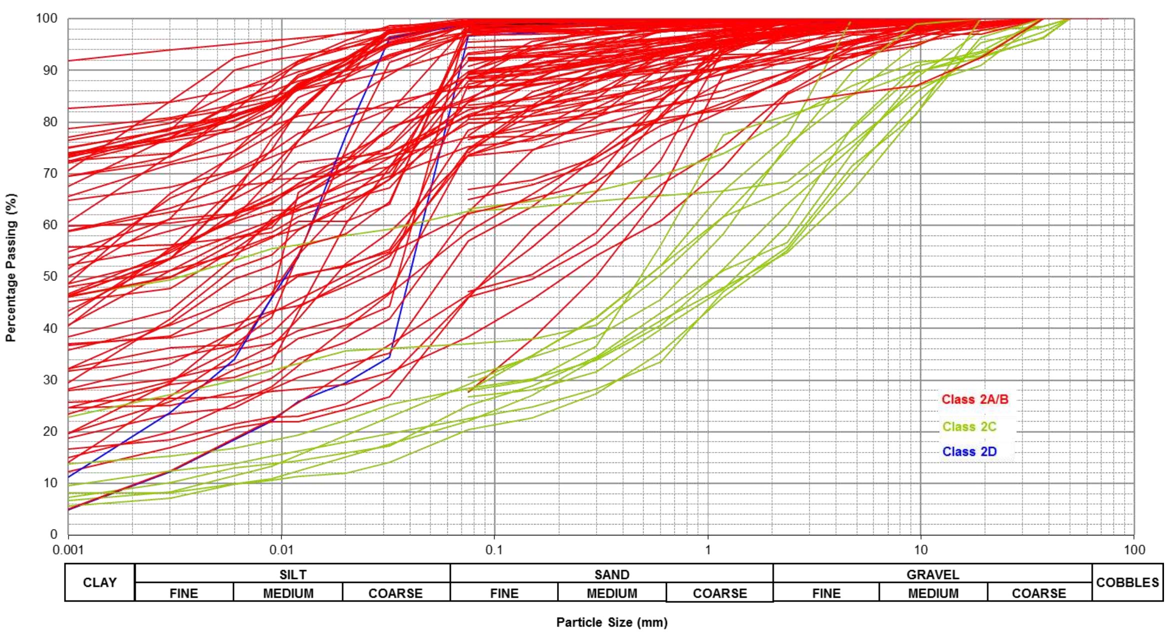

Figure 7. Particle size distributions for PRF

3.5 Strength

Strength profiling was undertaken using cone penetration testing (CPT) and standard penetration testing (SPT). Correlations for undrained shear strength and the cone tip resistance (q_c) measurement are shown in Figure 8 below where the N_K value of 18 for both ALF and PRF was used, based on the average plasticity index (I_P) values and total stress (σ_v), to evaluate undrained shear strength (s_u) following the well-established relationship (Bowles, 1996):

$$s_u = \frac{q_C - \sigma_v}{N_K}$$

where:

$$N_K = 13 + \frac{5.5}{50} I_P (\pm 2)$$

Here, a clear distinction can be made between the ALF and PRF soil units, with the PRF expressing a consistently higher strength profile.

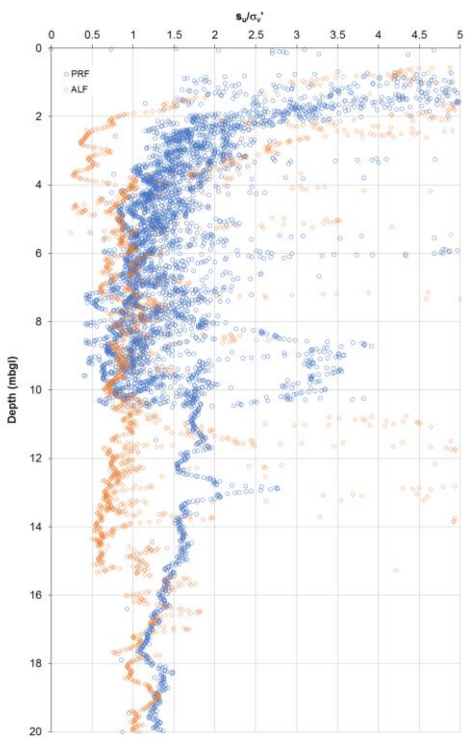

Figure 8. Normalised undrained shear strength profile for ALF and PRF soil units

Correlations with the corrected SPT results are presented in Figure 9. Trendlines are presented (assuming a zero intercept) for the ALF and PRF separately. The trends show that the ALF is consistent with normally adopted linear correlations of undrained shear strength equivalence to a multiple of 4.5 to 6 of the N_{60} result. The PRF however expressed higher strength, specifically a multiple of 6.35, i.e. approximately 18% higher than the ALF, on a linear trend.

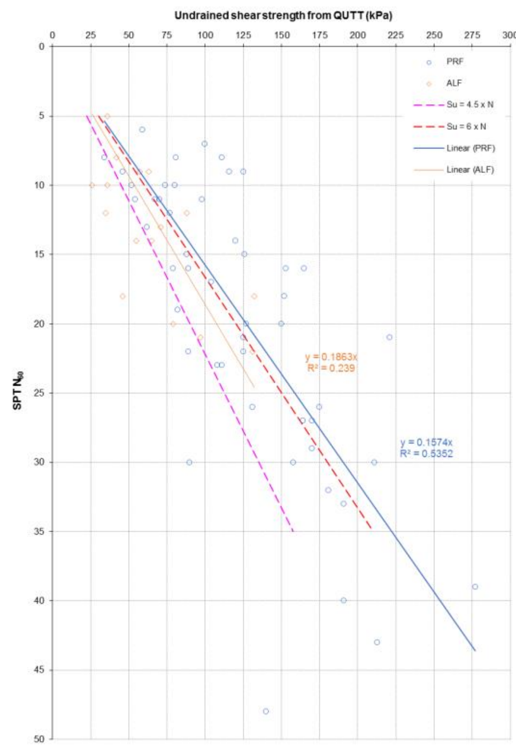

Figure 9. Correlation between corrected SPT N and undrained shear strength

Results of drained strength measurements are presented in Figure 10. Tests were undertaken as isotropically consolidated drained triaxial tests. In the plot of normal stress to shear stress, the ALF expressed near-zero cohesion intercept while the PRF expressed a cohesion intercept of 5.28kN/m^2. The corresponding angles of internal shearing resistance are 25.8° and 22.9° respectively.

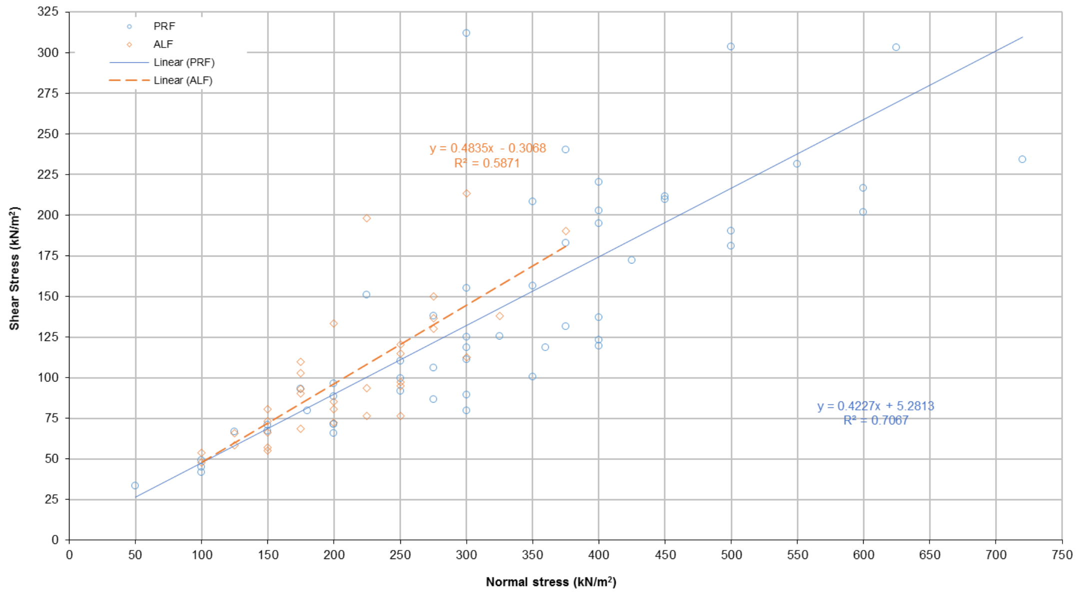

Figure 10. Effective stress measurements for ALF and PRF

4 CONCLUSIONS

While the mineral, depositional and geological differences between fine-grained alluvial and fine-grained proluvial soil units native to the study area in Kosovo are understood, use of index properties are not a reliable means to distinguish the materials. Similarly, the soil units will be consistent in terms of material grading in line with current UK-based classifications, typically as Class 2A/B materials, albeit the provulium typically has a higher fines content.

Estimates of stress history and strength (both undrained and drained), highlight the difference in the soil units more distinctly. The proluvium expresses higher undrained shear strength and a higher effective cohesion intercept than the alluvium. Tentative correlations are presented for undrained shear strength and the corrected standard penetration test result.

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6 REFERENCES

Ladd, C.C., Foott, R. (1974), “New design procedure for stability of soft clays” JGED, ASCE, col. 100, GT 7, July, pp, 763-786

Schmertmann, J.H. (1975), “The measurement of in situ shear strength” 7th PSC, ASCE, vol. 2, pp, 57-138

Bowles, J.E. (1996), “Foundation analysis and design” McGraw-Hill International Editions, pp, 172-177