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1. はじめに

本報告は Ch. Veder によって提案された地すべりの電気化学的な安定化工法¹⁾を本邦に適用した場合の調査結果について述べたものである。前報では、Veder の指適した土色分化を実験室内に再現し、導電体の効果について検討した結果、二層を貫いて挿入された導電体により、二層境界面付近の含水比分布および二層間の土の酸化還元反応に変化を生じることが確認された。実験工事は、新潟県砂防課により建設省土木研究所の地すべり試験地である新潟県猿供養寺地すべり地内の一区画で行なわれた。導電体挿入 1 年後の調査結果により、地すべり土塊、粘土中の化学的性質に変化が生じ、また地すべり土塊の自然含水比に変化が生じていることが判明した。

2. 実験方法

猿供養寺地すべりの地質、土質特性などはすでに報告されている。⁽²⁾ 図-1 に示す地点に導電体 4 本をボーリングで挿入し、根入れを基盤泥岩層 2 m において。1975 年 7 月に事前調査、1975 年 12 月に挿入工事をおこない、1976 年 1 月および 1977 年 1 月と約 1 年間追跡調査をおこなった。調査は約 4 m² の pit を基盤泥岩層まで掘削し、試料採取後、pH、Eh 自然含水比、および土の化学成分について分析をおこなった。

3. 結果および考察

導電体挿入後の土の pH の変化について図-2 に示す。pit-No 2 は事前調査、No. 3 は挿入後 10 日後、No. 4 は 1 年経過後、No. 5 は 1 年経過後の挿入区域外の調査結果である。深さの表示は地すべり面を基準して記載した。導電体挿入 1 年経過後、表土層で、pH は低下し、地すべり面上部層は pH=1 程度上昇していた。地すべり面下層では、ほぼ一定の pH=8~9 の値であった。図-3 は、Eh の測定結果を示す。測定値は飽和甘永電極比較値で示した。Eh は、一側から十側に移行し、1 年経過後では地すべり面上下層の電位が一定化する傾向があらわれた。次に自然含水比の変化を図-4 に示す。表層の含水比は、積雪の関係か含水比が全般的に高く測定された。Eh が十側に移行した 1 年経過後の pit-No. 4 では、地すべり面上部層で平均的に 5 % 程度減少していた。

地すべり面の含水比は、有意な差は認められず、これはすべり面の厚さが数 mm 程度であるため、試料採取時に誤差が生じたためと考えられる。以上の結果から、導電体の挿入は、土の酸化還元反応に影響を及ぼすものと考えられ、次に、実際の酸化還元反応物質として No. 4 と No. 5 の試料の第 1 鉄、遊離酸化鉄の測定をおこない、それに伴っておこる化学的性質の変化について検討した。

表-1 は、C.E.C. 交換性陽イオン、第 1 鉄/遊離鉄及び脱鉄処理後の C.E.C. の測定結果を示したものである。C.E.C. の測定は風乾試



図-1 実施区域

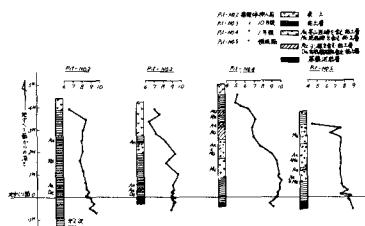


図-2 pH の経年変化

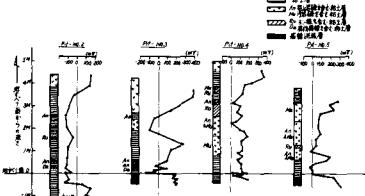


図-3 酸化還元電位の経年変化
(飽和甘こう電極の読み値)

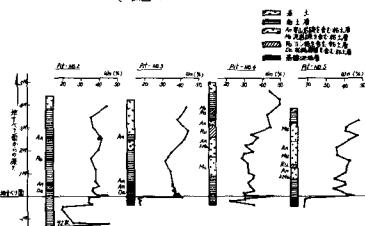


図-4 自然含水比の経年変化

料を Ca-Na の交換法で、交換性陽イオンは酢酸アンモニウム抽出法で第 1 鉄量は pH=3 の塩酸一酢酸 Na 緩衝液で現地すぐ固定し、同液で抽出後比色法で分析した。遊離鉄は風乾試料を Mela-Jackson 法で脱鉄処理し、その後の試料の減量から算定した。結果を表-1 に示す。

まず（第 1 鉄／遊離鉄）は、導電体挿入区で、表層から -2m、地すべり面およびその下層で著しく減少していた。これは Eh の測定結果とよく対応し、導電体挿入によって土が還元状態から酸化状態に明らかに変化したことになり、第 1 鉄は酸化され水酸化第 2 鉄などの遊離酸化鉄を生成したことになる。この第 1 鉄含有量の減少に伴って、交換性陽イオンの Na イオンが減少し、地すべり面上部層に他の陽イオンと共に集積する傾向が得られた。風乾試料の C.E.C. は両者大差ないが、脱鉄処理後両者とも 4 ~ 12 meq/100g 上昇し、遊離酸化鉄が粘土の負電荷面を被覆していることがわかった。すなわち、導電体挿入区は、遊離酸化鉄の生成によって粘土の負電荷面が減少しそれに伴って交換性陽イオンが下層に移行、ないしは溶脱されたものと考えられる。一般に溶脱しやすい陽イオンは Na > K > Mg > Ca といわれており、⁽³⁾ 本結果とよく一致する。塩基飽和度も、Na イオンの減少傾向と一致し、導電体挿入区で不飽和になり、さらに粘土コロイドにしめる 2 倍の陽イオンの比も明らかに多くなった。粘土に吸着している交換性陽イオンは粘土の電気二重層の厚さの指標であるから、2 倍の陽イオンの増加は電気二重層が薄くなつたことをしめし、粘土が互いに凝集しやすい状態にあることをしめしている。水田土壤などの排水不良な土壤では土の团粒構造発達に遊離酸化鉄が関係している。⁽⁴⁾ したがって、導電体の挿入は、地すべり土中の第 1 鉄を遊離酸化鉄に酸化し、土の界面化学的性質を変化させ、土粒子を互いに凝集團粒化させる効果をもつことが考えられる。これは、表層部の pH の低下、交換性陽イオンの地すべり面上部層の集積および pH の上昇といった土の化学的性質の変化からも想定される。

本調査で、Veder のいう自然電位解消による地すべり土の改良について明確な証拠をつかむことは出来なかつた。自然電位を個別に解析出来なかつたためである。しかし、地すべり土層の酸化還元反応が変化する結果が得られたことは、本工法が還元状態で封鎖されている電子を導電体を通して酸化層に移動させいわゆる二層の酸化還元平衡をならしめる効果をもつことは十分想定出来る。さらに表層は大気にふれ酸素分圧も高く、この平衡反応は常に酸化側に移行し、効果は下層にまでおよび、還元物質（鉄、マンガン、硫化物、有機物）がなくなるまで進む状態になるものと考えられる。

4. あとがき

本報告は、広い猿供養寺地すべり地の一角の結果を示したものであり、断面形状も異なり、力学的内容も検討を加えていないし、測定結果も一例にすぎない。今後さらに、他の地すべり地への適用、規模の拡大をはかると共に、本調査結果にもとづく室内実験等、総合的見地で検討を加えていく所存である。

表-1 導電体挿入区と挿入区域外の断面試料の化学成分

| P-1 | P-2 | P-3 | P-4 | P-5 | P-6 | P-7 | P-8 | P-9 | P-10 | P-11 | P-12 | P-13 | P-14 | P-15 | P-16 | P-17 | P-18 | P-19 | P-20 | P-21 | P-22 | P-23 | P-24 | P-25 | P-26 | P-27 | P-28 | P-29 | P-30 | P-31 | P-32 | P-33 | P-34 | P-35 | P-36 | P-37 | P-38 | P-39 | P-40 | P-41 | P-42 | P-43 | P-44 | P-45 | P-46 | P-47 | P-48 | P-49 | P-50 | P-51 | P-52 | P-53 | P-54 | P-55 | P-56 | P-57 | P-58 | P-59 | P-60 | P-61 | P-62 | P-63 | P-64 | P-65 | P-66 | P-67 | P-68 | P-69 | P-70 | P-71 | P-72 | P-73 | P-74 | P-75 | P-76 | P-77 | P-78 | P-79 | P-80 | P-81 | P-82 | P-83 | P-84 | P-85 | P-86 | P-87 | P-88 | P-89 | P-90 | P-91 | P-92 | P-93 | P-94 | P-95 | P-96 | P-97 | P-98 | P-99 | P-100 | P-101 | P-102 | P-103 | P-104 | P-105 | P-106 | P-107 | P-108 | P-109 | P-110 | P-111 | P-112 | P-113 | P-114 | P-115 | P-116 | P-117 | P-118 | P-119 | P-120 | P-121 | P-122 | P-123 | P-124 | P-125 | P-126 | P-127 | P-128 | P-129 | P-130 | P-131 | P-132 | P-133 | P-134 | P-135 | P-136 | P-137 | P-138 | P-139 | P-140 | P-141 | P-142 | P-143 | P-144 | P-145 | P-146 | P-147 | P-148 | P-149 | P-150 | P-151 | P-152 | P-153 | P-154 | P-155 | P-156 | P-157 | P-158 | P-159 | P-160 | P-161 | P-162 | P-163 | P-164 | P-165 | P-166 | P-167 | P-168 | P-169 | P-170 | P-171 | P-172 | P-173 | P-174 | P-175 | P-176 | P-177 | P-178 | P-179 | P-180 | P-181 | P-182 | P-183 | P-184 | P-185 | P-186 | P-187 | P-188 | P-189 | P-190 | P-191 | P-192 | P-193 | P-194 | P-195 | P-196 | P-197 | P-198 | P-199 | P-200 | P-201 | P-202 | P-203 | P-204 | P-205 | P-206 | P-207 | P-208 | P-209 | P-210 | P-211 | P-212 | P-213 | P-214 | P-215 | P-216 | P-217 | P-218 | P-219 | P-220 | P-221 | P-222 | P-223 | P-224 | P-225 | P-226 | P-227 | P-228 | P-229 | P-230 | P-231 | P-232 | P-233 | P-234 | P-235 | P-236 | P-237 | P-238 | P-239 | P-240 | P-241 | P-242 | P-243 | P-244 | P-245 | P-246 | P-247 | P-248 | P-249 | P-250 | P-251 | P-252 | P-253 | P-254 | P-255 | P-256 | P-257 | P-258 | P-259 | P-260 | P-261 | P-262 | P-263 | 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