Development of Landfill Material by Utilizing Waste Lime

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요 지

인천 해안지역을 중심으로 송도 신도시 개발과 인천 국제공항 공사는 공유수면을 대규모로 매립하여 지반을 조성하고 있다. 현재까지 막대한 양의 준설토를 매립에 사용한 결과로 양질의 매립토 확보에 상당한 어려움을 겪고 있는 실정이다. 이러한 현실성을 고려하여 소다회를 생산하고 부산물로 발생되는 폐석회를 화강풍화토와 혼합하여 매립재로 활용할 수 있는 방법에 대하여 연구를 수행하였다. 환경실험을 통하여 화학적 성분, pH, 중금속함량 등을 측정하여 환경적 영향에 대하여 검토를 수행하였다. 또한 혼합비에 따른 다짐시험, 일축압축강도시험, X-ray 회절분석시험 등을 수행하여 강도증가 및 매립재로서의 활용가능성을 검토하였다. 상기의 연구결과 폐석회를 화강풍화토에 무게중량으로 20%를 혼합하면 양호한 매립재로 활용이 가능하며, 환경적 영향도 국내 관련기준법을 만족함을 알 수 있다.

Abstract

The feasibility of using waste lime, which is produced as a byproduct during the manufacture of sodium carbonate in Inchon, Korea, as a stabilization admixture with weathered granite soil was investigated. Laboratory tests were conducted to determine the chemical composition, pH, compaction characteristics, unconfined compression strength, X-ray diffraction analysis of waste lime and weathered granite soil admixtures. Based on the present tests, it appears that the admixtures are environmentally safe and can be used as landfill material.

Keywords : Chemical composition, Compaction, Stabilization, Unconfined compression strength, Waste lime, Weathered granite soil

1. Introduction

Several major land reclamation projects are now under way along the coastal areas of Inchon, Korea. Two examples are the Inchon International Airport construction and the Songdo New City

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construction. For these reclamation projects and other future projects, large quantities of fill material will be required. In Inchon, large stockpiles of waste lime (hydrated lime) are produced as a byproduct during the manufacture of sodium carbonate (Na_2CO_3). At present there is an accumulation of about 300 million tons of waste lime, and about 100,000 tons are produced per year. Due to the associated environmental issues, it seems prudent to use this waste lime in construction projects as a fill material.

Lime has been used as an admixture for stabilization of clay soils in many parts of the world. Research works(e.g., Herzog and Mitchell, 1963; Diamond and Kinter, 1965; Ingles and Metcalf, 1972; Clare and Cruchley, 1957; Eades and Grim, 1960; Arman and Munfakh, 1972; Neubauer and Thompson, 1972) have shown that clay soil stabilization with lime is a viable alternative.

The top soil in a large part of Korea consists of weathered granite. This paper is a summary of a study conducted in the laboratory to determine the feasibility of using waste lime mixed with weathered granite soil as a fill in those construction projects.

2. Chemical Compositions and Physical Properties

Standard laboratory tests on representative specimens of waste lime and weathered granite soil were conducted to determine their chemical composition and physical properties. These are summarized in Table 1. The grain-size distributions of waste lime and decomposed granite are shown in Fig. 1. Figure 2 shows a scanning electron micrograph of waste lime. It can be seen that waste lime is mostly nonuniform and sub-angular in shape.

Table 1. Chemical composition and physical properties of waste lime and weathered granite soil

Item	Waste lime	Weathered granite
Chemical Composition(in %)		
SiO_2	11.2	61.1
Al_2O_3	3.1	17.5
Fe_2O_3	2.2	6.1
CaO	34.5	1.8
MgO	11.5	0.9
K_2O	0.9	3.5
Na_2O	0.9	3.3
TiO_2	–	1.0
Loss on ignition	36.1	4.9
Physical Properties		
Passing No. 200 U.S. sieve(0.075mm opening)	97.5%	26.5%
Specific gravity of soil solid, Gs	2.15	2.57
Maximum dry unit weight of Compaction (standard), $\gamma_{d(max)}$	11.7kN/m^3	17.9kN/m^3
Optimum moisture content	39.7%	12.9%
Liquid limit	63	25
Plastic limit	52	Nonplastic
Unified classification	MH	SP-SM

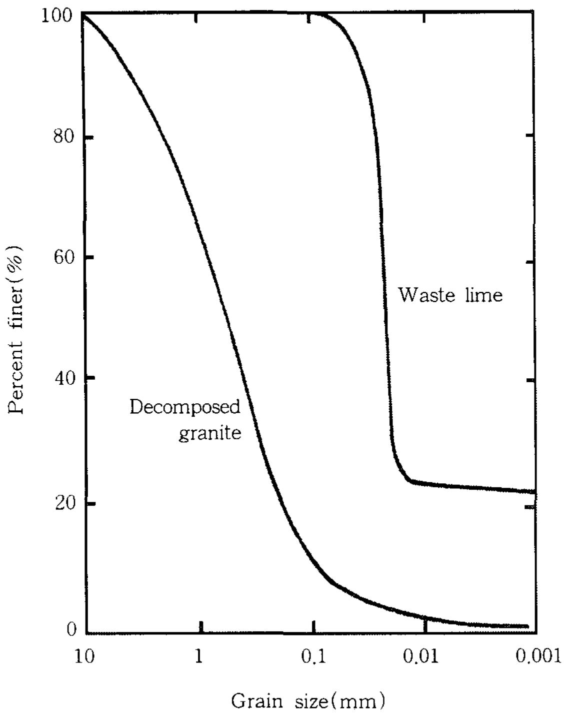

Fig 1. Grain-size distribution of decomposed granite and waste lime

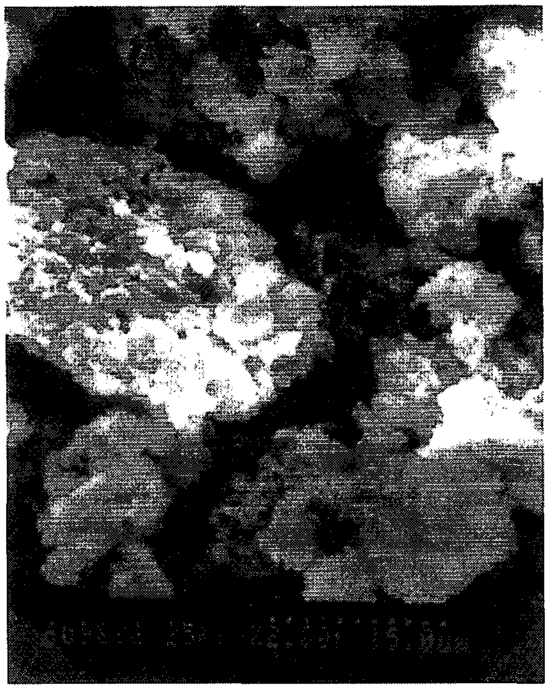

Fig 2. Scanning electron micrograph of waste lime

Environmental tests were also conducted for waste lime to determine typical heavy metal components. The results are summarized in Table 2 along with the existing Korean MOE standards. Based on these results it can be concluded that waste lime does meet the Korean MOE standards for using as a landfill material.

Table 2. Environmental test results for waste oime

Metal	Quantity in Waste lime(mg/L)	Korea MOE Standards(mg/L)
Pb	Not detected	3.0
Cd	0.05	0.3
Cr	Not detected	1.5
Cu	0.04	3.0
Hg	Not detected	0.005
As	Not detected	1.5
Cn	Not detected	1.0

3. Laboratory Testing of Weathered Granite Soil and Waste Lime Mixtures

The following laboratory tests were conducted by mixing weathered granite soil and waste lime in various proportions (by weight): (a) pH tests, (b) Proctor compaction tests, and (c) unconfined compression tests. The details of these tests are described below.

pH test

pH tests were conducted by mixing waste lime and weathered granite soil in various proportions by weight. The pH of 100% weathered granite soil and waste lime were 4.99 and 9.51, respectively. Table 3 gives the pH values of various mixtures, and this is also shown in a graphical form in Fig 3.

Table 3. pH test results of soil oixtures

% waste lime / % granite soil (by weight)	pH
0/100	4.99
10/90	7.07
15/85	7.39
20/80	7.41
30/70	7.47
40/60	7.54
50/50	9.51

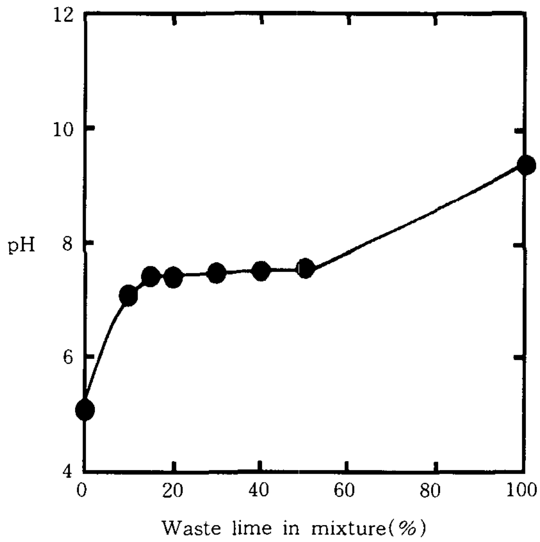

Fig. 3 Variation of pH with percent of waste lime in the mixture

Proctor Compaction Test

Standard Proctor compaction tests were conducted for various mixtures of waste lime and weathered granite soil. The variation of the dry unit weight (γ_d) vs. moisture content (w) is shown in Fig. 4. Figure 5 shows the plots of maximum dry unit weight [$\gamma_{d(max)}$] and optimum moisture content(w_{opt}) for the mixtures. This figure shows that the maximum dry unit weight of the mixtures gradually decreases with the increase in lime content which is accompanied by an increase in the optimum moisture content.

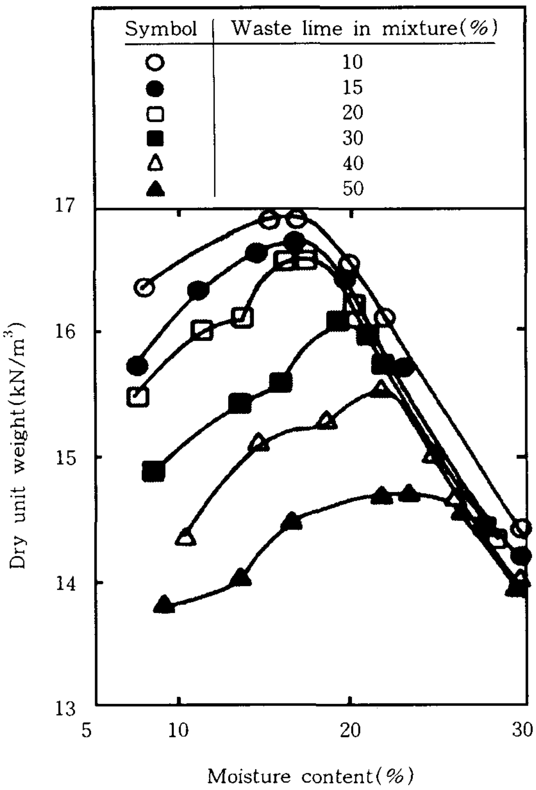

Fig. 4 Variation of dry unit weight with moisture content

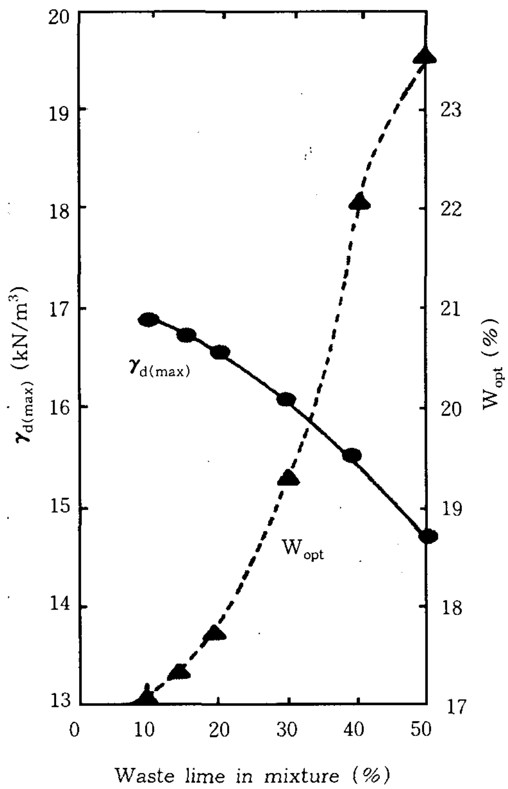

Fig. 5 Variation of $\gamma_{d(max)}$ and w_{opt} with percent of waste lime in mixture

Unconfined Compression Test

Unconfined compression tests were performed with waste lime and weathered granite soil mixtures. The percentage of the waste lime by weight in the mixture was varied at 10%, 15%, 20%, 30%, 40%, and 50%. The test specimens were prepared in a plastic mold by applying similar energy of compaction to that applied in standard Proctor compaction tests. The plastic mold had an inside diameter of 50mm and a height of 125mm. The moisture content of the specimens was the same as the optimum moisture content as determined from the standard Proctor compaction tests. The specimens were cured for 0, 1, 3, 7, 14, 28, and 45 days before tests were conducted. The curing temperature was 25℃. The variations of the unconfined compression strength (q_u) with curing time and waste lime percentage are shown in Fig. 6. It can be seen from this figure that, for any curing period, specimens prepared with 20% waste lime had the highest unconfined compression strength. For any given mixture, the magnitude of q_u increased rapidly with the increase in curing period up to 28 days due to the appearance of CSH(Ⅱ) and CSH(Ⅰ). This is shown in Figure 11. For curing period greater than 28 days, the rate of increase in q_u decreased.

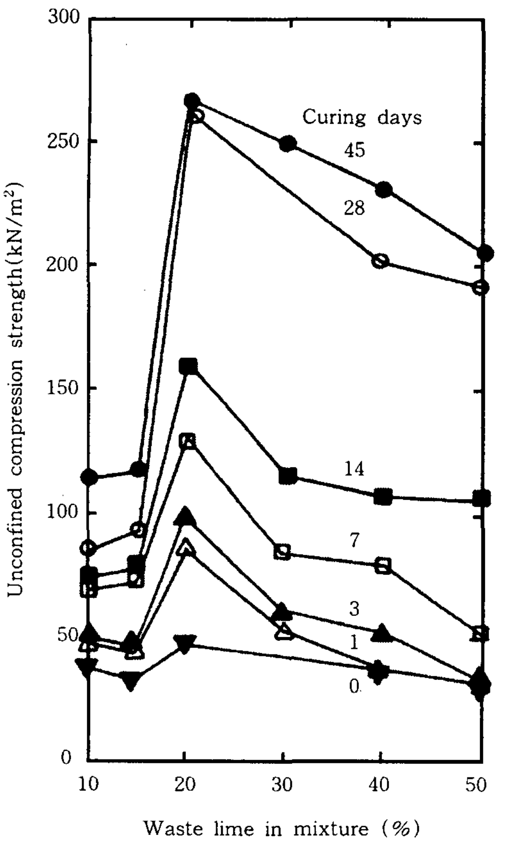

Fig. 6 Unconfined compression strength of waste lime and decomposed granite mixtures

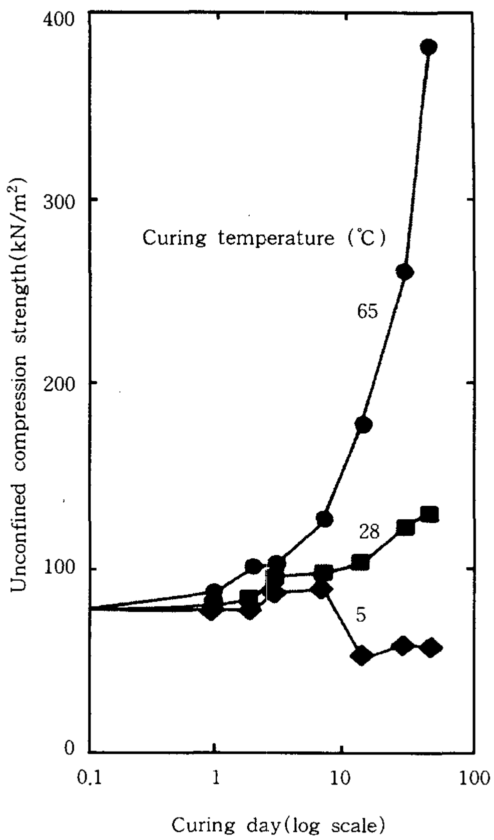

Fig. 7 Unconfined compression strength of waste lime specimens at various temperatures

Additional unconfined compression tests were also conducted on waste lime specimens only (compacted with standard Proctor compaction test energy at optimum moisture content) to study the effect of the curing temperature and time of curing. The maximum dry unit weight and optimum moisture content for waste lime only were determined previously (by conducting standard Proctor compaction tests) to be 11.7kN/m^3 and 39.7%, respectively. The curing temperature of the unconfined compression test specimens were varied at 5℃, 28℃, and 65℃. The variations of qu obtained from these tests are given in Fig. 7. From these test results it appears that greater strength gain is realized for curing temperature greater than about 28℃. The backfill material is usually placed after construction of sea dike. Dredged soil is filled around the sea dike. So, there is a possibility that waste lime stabilized soil can have indirectly contact with salty water. The magnitude of shear strength decrease should be studied, but it may not be a serious problem.

X-Ray Diffraction Analysis

X-ray diffraction analysis was conducted on the decomposed granite soil, waste lime, and mixed specimen consisting of 20% waste lime and 80% decomposed granite soil. The curing days for waste lime stabilized soil were varied from 0 to 45 days. Figures 8 and 9 show the results of the X-ray diffraction analysis on the decomposed granite soil and waste lime, respectively.

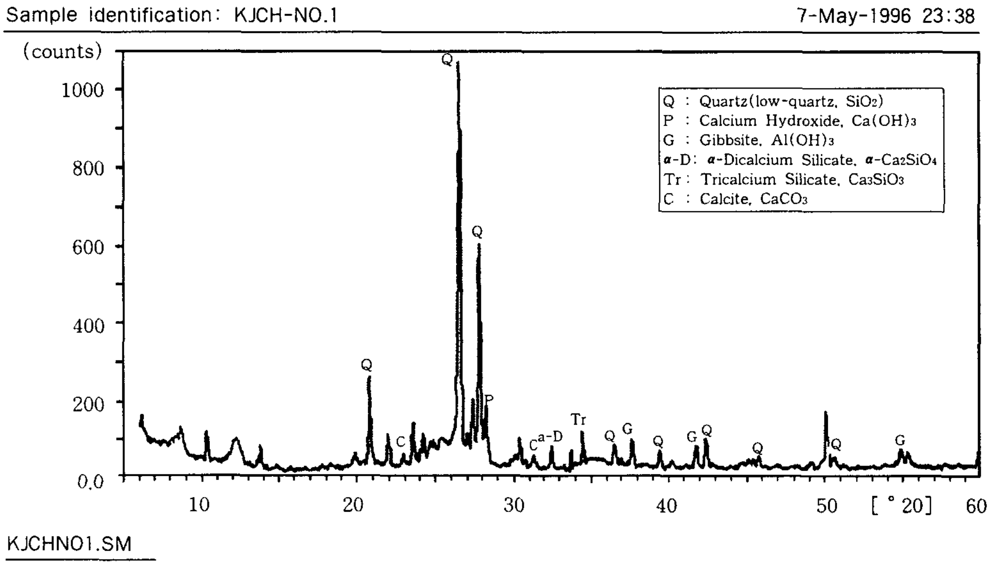

Fig. 8 X-ray diffraction analysis result of decomposed granite soil

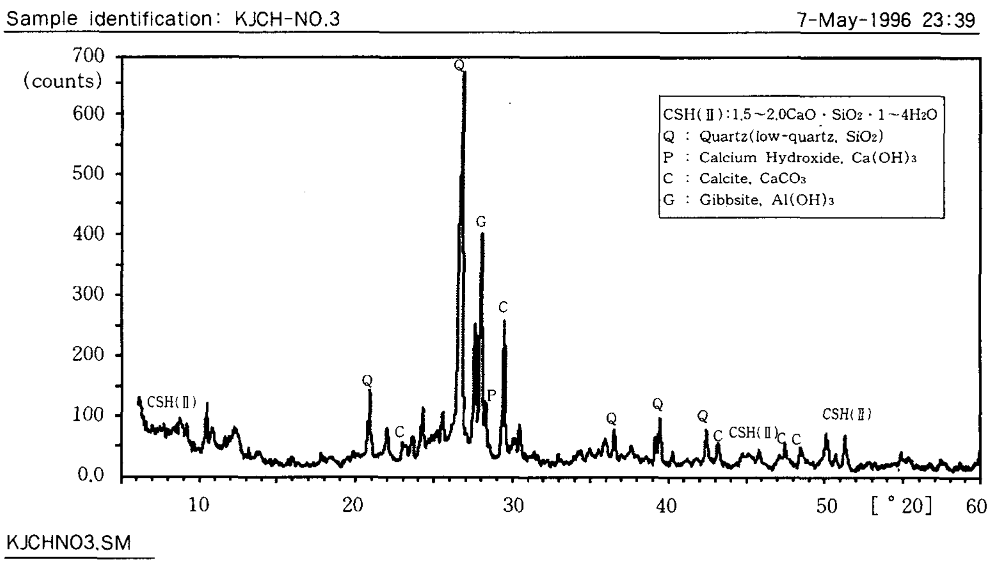

Fig. 9 X-ray diffraction analysis result of waste lime

The decomposed granite soil shows high content of quartz and gibbsite minerals than those of waste lime. This paper presents only the results of X-ray diffraction analysis of 1day curing mixed specimen (Figure 10) and 45 days curing mixed specimen (Figure 11) for the purpose of comparison. From these figures, CSH(Ⅱ) which contains 1.5~2.0 $CaO \cdot SiO_2 \cdot 1\sim4H_2O$ was created in the short term curing period, while CSH(Ⅱ) and CSH(Ⅰ) which contains 0.8~1.5 $CaO \cdot SiO_2 \cdot 0.5\sim2.5H_2O$ were appeared in the long term curing period.

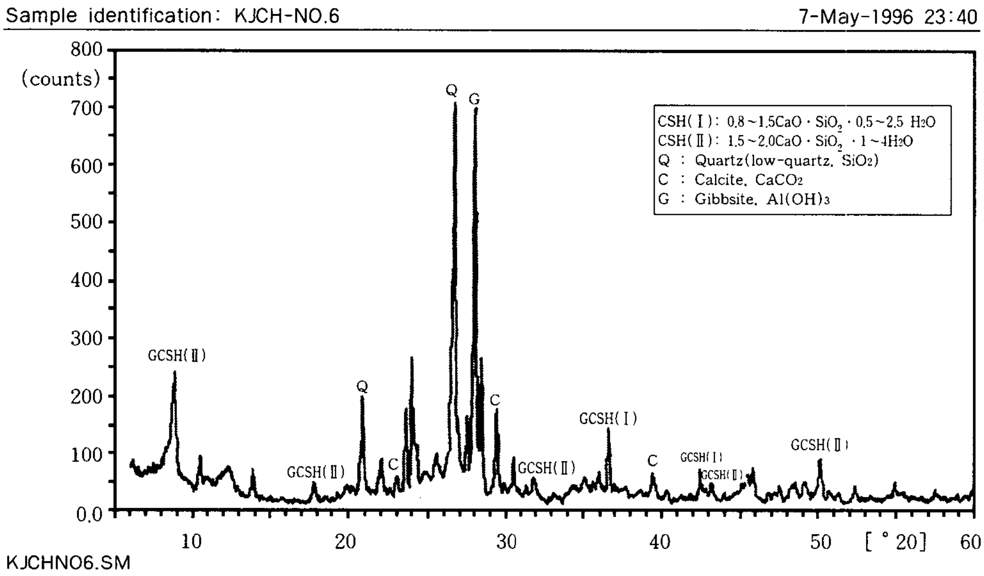

Fig. 10 X-ray diffraction analysis result of 1day curing mixed specimen

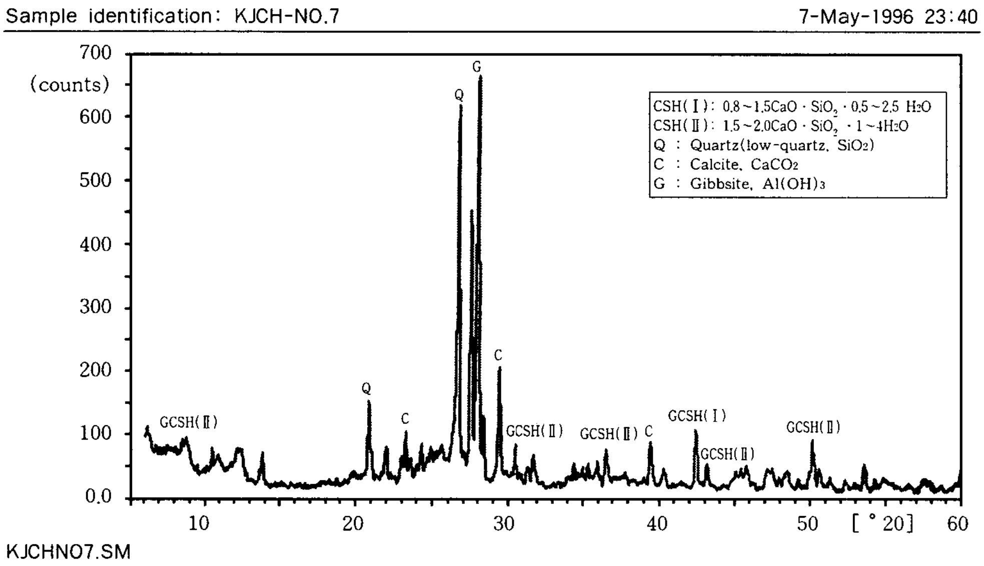

Fig. 11 X-ray diffraction analysis result of 45 days curing mixed specimen

4. Conclusions

Several laboratory tests were conducted on waste lime and decomposed granite soil mixtures to determine the feasibility of using them as a fill material in the coastal land works in Korea. Based on the laboratory test results, the following conclusions can be drawn:

1) About 20% by weight of waste lime can be mixed with 80% of decomposed granite soil to obtain maximum strength in a compacted condition.
2) The chemical composition of waste lime is such that its utilization in land reclamation is environmentally safe.
3) The unconfined compression strength of mixed soil increases with the increase of curing temperature and curing day with exception of curing temperature 5°C.
4) The components of minerals change with curing days for waste lime - soil mixed specimen.

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