SPECTRAL ANALYSIS OF BUILDING MATERIALS USED IN JAPAN

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ABSTRACT:

To conduct appropriate urban planning for a given area, understanding latent urban problems such as excessive concentration of population, aging of residents, and grasping temporal changes in both societal and physical structures in the area are important. In this study, as a basis for the development of the descriptive indices for urban characteristics, we discuss the applicability of remote sensing techniques to classify urban surface materials commonly used in Japan, based on an analysis of spectral reflectance data, ranging from 350 nm to 2500nm, of various rooftop and road pavement materials, which were collected for this study with a field spectrometer. The building materials collected in the field measurement were a set of roof top materials including Japanese roof tiles, tin sheets, natural and artificial roofing slates, waterproof sheets, as well as a set of road pavement materials including asphalt surfaces, pervious pavement tiles, with various colors, set in an outdoor experiment field simulating urban land use. In the field measurement, some of the materials were measured under multiple solar conditions by changing solar incident angles and sensor directions so that the influence of observation conditions could be analyzed. The results of the spectral analysis suggest that many roofing materials studied in this paper showed relatively similar reflectance patterns in visible part of the spectrum. Those materials, however, displayed noticeable differences from one another in the spectral responses in the infrared range. Regarding the road pavement materials, distinctive spectral characteristics were observed also in the infrared range.

1. INTRODUCTION

The “Fundamental Principles of Policy for Creation of Beautiful Country” established in 2003 in Japan and the “Landscape Act” established in 2004 demand conservation of the natural landscape, conservation of historical buildings and the appearance of streets, and formation of good landscapes in cities, as well as in farming, fishing, and mountain villages. In order to objectively promote formation of such good landscapes, it is desired to establish quantitative indices for the assessment of the present situation of the appearance of streets and assessment of the impacts of landscape-related administrative measures. Basic data that comprise such indices, including the material and shape of buildings in the area subject to assessment, information about the density and green coverage ratio, and historical and cultural elements must be prepared with uniform accuracy widely in all cities throughout Japan. However, detailed geographical information regarding urban characteristics at such a level has not been prepared yet in Japan. To grasp building materials consisting of given study areas could be an important component of the above-mentioned indices. Remote sensing technique that collects information about the spatial entities on the ground, especially airborne hyperspectral remote sensing that ensures a detailed spatial resolution, is considered to be suitable for a wide-area survey that has both reproducibility and efficiency good enough to collect detailed information such as surface materials comprising of urban landscapes. There are previous works studied the urban mapping capabilities of hyperspectral remote sensing (Ben-Dor et al., 2001; Chen & Hepner, 2001; Herold et al., 2004). The subjects studied in the previous studies, however, are mostly building materials commonly used in Western countries in Europe and the US, and spectral analyses of building materials often used in Asian countries have not been often discussed. Concerning the above, the authors have been engaged in a development of an urban data collection method that uses the hyperspectral remote sensing technique as well as the integration of multiple airborne remote sensing technologies to provide advanced urban spatial data set.

As part of the basic examination of the above mentioned project, the spectral reflectance library of various roof materials and road pavement materials was acquired using a ground-based spectrometer to see if the remote sensing technique could permit classification of materials.

2. URBAN SPATIAL INFROMATION COLLECTION USING AIRBORNE REMOTE SENSING

Concerning airborne remote sensing technique to collect special information about urban areas, the authors are developing an integrated method by combining multiple aerial remote sensing techniques shown below.

2.1 Classification of spatial objects based on spectral characteristics

Classification of urban spatial objects based on the difference in spectral characteristics of surface materials including building construction materials and classification of road pavement

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materials by visual and automatic classification of the spectral reflectance data.

2.2 Geometrical analysis of building shapes using three-dimensional airborne laser scanning data

Reconstruction of the shapes of buildings as computer models from laser scanning point data taken from airplanes to classify the shapes and dimensions of buildings, density, and other geometrical features by computer processing

2.3 Additional information from GIS

We also utilize supplemental geographic information including city planning maps and historical maps to support urban information extraction.

The authors intend to establish objective indices to the classification and assessment of the landscape of urban areas by appropriately combining the information collected by the techniques mentioned above. In order to examine the possibility of classification of ground covers based on the spectral characteristics described in 2.1, a spectral reflectance library of various kinds of roof materials and pavement materials were collected in this study and the result was examined.

3. METHODOLOGY

This study comprises the measurement of spectral reflectance and the examination of the result.

3.1 Definition of spectral reflectance

An individual object shows a specific spectral reflectance according to the material composition and the condition of the surface.

Spectral reflectance is defined as follows:

$$R\lambda_i = \frac{\text{Rad } i\lambda_i}{\text{Rad } r\lambda_i}$$

where, $R\lambda_i$: Spectral reflectance at wavelength λ_i

Rad $i\lambda_i$: Radiance ($W \cdot cm^{-2} \cdot sr^{-1} \cdot nm^{-1}$) of the subject at wavelength λ_i

Rad $r\lambda_i$: Radiance ($W \cdot cm^{-2} \cdot sr^{-1} \cdot nm^{-1}$) of standard white plate ($BaSO_4$) at wavelength λ_i

3.2 Spectral data acquisition

In this study, spectral reflectance data were captured using ASD Field Spec 3 spectrometer (Analytical Spectral Devices, Inc., Boulder, CO, USA), which has been widely used in the field of remote sensing. Observation was repeated ten times for one subject, and the results were averaged to find the final measurement value.

A device called a high intensity contact probe was attached to the aperture of the spectrometer to allow contact with the surface of the subject so as to avoid the influence of the external illumination. Some objects were observed by changing the relative angle between the sun and the sensor at several steps to see if the change in the direction of the observation sensor and the change in the solar azimuth angle and elevated angle would make difference in the observation results.

3.3 Subjects of Spectral Observation

Subjects of the hyperspectral observation were selected from a variety of construction materials installed in the exposure test field of the Building Research Institute Japan to carry out observation. (Permeable pavement materials were tested indoors.)

The materials analyzed in this study are shown below.

3.3.1 Roof material

Natural slate (black)
Artificial slate (red)
Artificial slate (black)
Galvanized sheet iron (white)
Japanese-style roof tile (black)
Concrete roof tile (blue)

3.3.2 Pavement material

Asphalt: 1 - 4
(Asphalt was classified into four types according to the color tone and grain size of the surface, and numbers 1 - 4 were given for descriptive purpose.)
Permeable pavement material: Dark blue and deep black
（Model FS H60F1, Nihon Kogyo Co., Ltd.)

4. POSSIBILITY OF CLASSIFICATION OF ROOF MATERIALS BY SPECTRAL INFORMATION

4.1 Spectral reflectance characteristics of the subjects

Figure 1 shows the result of measurement of the spectral reflectance of roof materials by a ground-based spectrometer. The reflectance of the galvanized sheet iron (white) is comparatively high within the entire range from 300 to 2,500 nm, while that of the other materials is comparatively low. Especially in the case of the materials other than the galvanized sheet iron, the reflectance concentrates in a comparatively small and low reflectance range from 300 nm to 700 nm, which makes up a substantial portion of visible light.

Contrary to the similarity in the visible spectrum, the dispersion of the spectral reflectance of respective materials is conspicuous in the infrared region where the wavelength is longer than 800 nm. For example, both the Japanese-style roof tile and the natural slate are black and similar to each other, but in the infrared area with longer wavelength, the reflectance of the Japanese-style roof tile is high, while that of the natural slate remains low, permitting easy classification of the two.

Meanwhile, conspicuous difference was not observed in this study while the directions of the sensor with respect to a subject and the directions of sunlight incidence were changed.

4.2 Discussion on the possibility of classification by spectral characteristics

Figure 2 shows the first-order derivatives of the spectral reflectance curves, which enhance the waveform characteristics of the spectral reflectance curves, by indicating the break points of the curves. The difference among various roof materials is comparatively clear in both Figure 1 and Figure 2. (In specific wavelength areas (near 1,400 nm and 1,800 nm, for example), however, absorption by the vapor and particles in the atmosphere is substantial, and the information collected by airborne remote sensing may be unusable.) According to the result shown above, the airborne remote sensing technique is considered to permit efficient classification of roof materials at the level of classification studied this time if the spectral reflectance characteristic similar to that obtained by the current ground-based observation is presumable.

5. POSSIBILITY OF CLASSIFICATION OF ROAD PAVEMENT MATERIALS BY SPECTRAL INFORMATION

5.1 Spectral reflectance characteristics of the subjects

Figure 3 shows the measurement result of the spectral reflectance of road pavement materials, acquired with a ground-based spectrometer.

Unlike the roofing materials, the asphalt and permeable tiles of

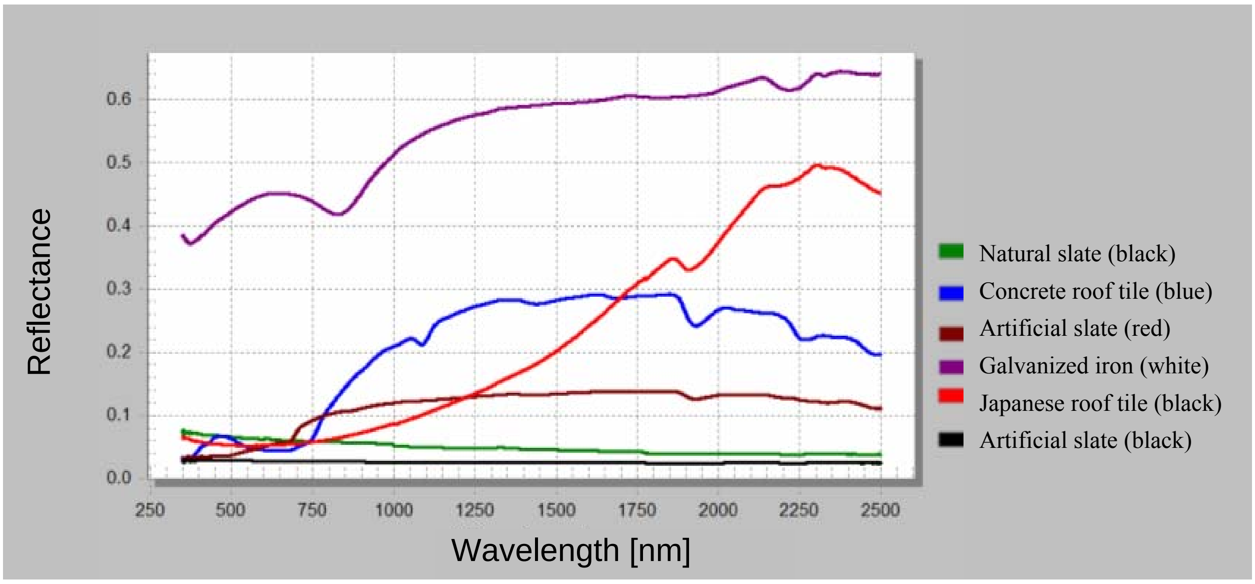

Figure 1. Spectra of roof materials

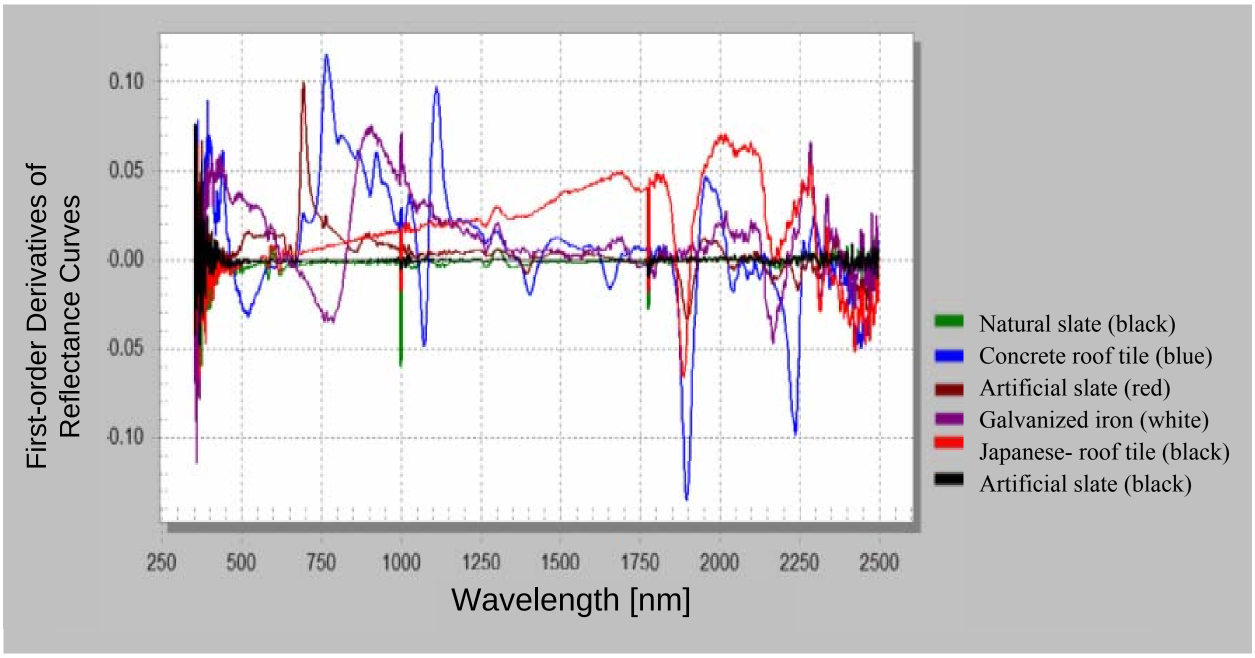

Figure 2. First-order derivatives of spectral reflectance curves of roof materials

respective types showed conspicuous difference in the visible wavelength region ranging from 500 to 800 nm.

The above fact can be also seen in the first-order derivatives of the spectral reflectance curves shown in Figure 4. In the 900 nm or longer wavelength infrared area, the values of respective materials are almost the same, and classification of the road surface materials studied in this paper based on the spectral characteristics in that region appears to be difficult.

5.2 Examination of the possibility of classification by spectral characteristics

The spectral reflectance curves and their first-order derivatives of the road surface materials seem to suggest the possibility of classification of asphalt and permeable pavement materials when the degree of reflectance in the visible and near infrared areas from 500 to 900 nm, as well as the shape of the curves, is analyzed.

The four types of asphalt analyzed in this study had surfaces with different brightness, which are classified into dark and slightly bright surfaces. This fact is reflected as the difference in the magnitude of spectral reflectance. However, since the curve profiles of the graphs are almost identical, classification based on the shapes of the first-order derivative curves would be difficult. Classification of the four types based on the spectral reflectance is comparatively easy under the controlled lighting condition adopted during this experiment, but further examination is necessary to see if such classification is possible during observation in natural light. In the same way, the first-order derivatives of the reflectance curves of the two types of permeable tiles bear a close resemblance to each other, and detailed examination of the spectral reflectance is necessary to distinguish the two based on the spectral information. The result of this study suggests that classification at the level of asphalt and permeable pavement materials will be

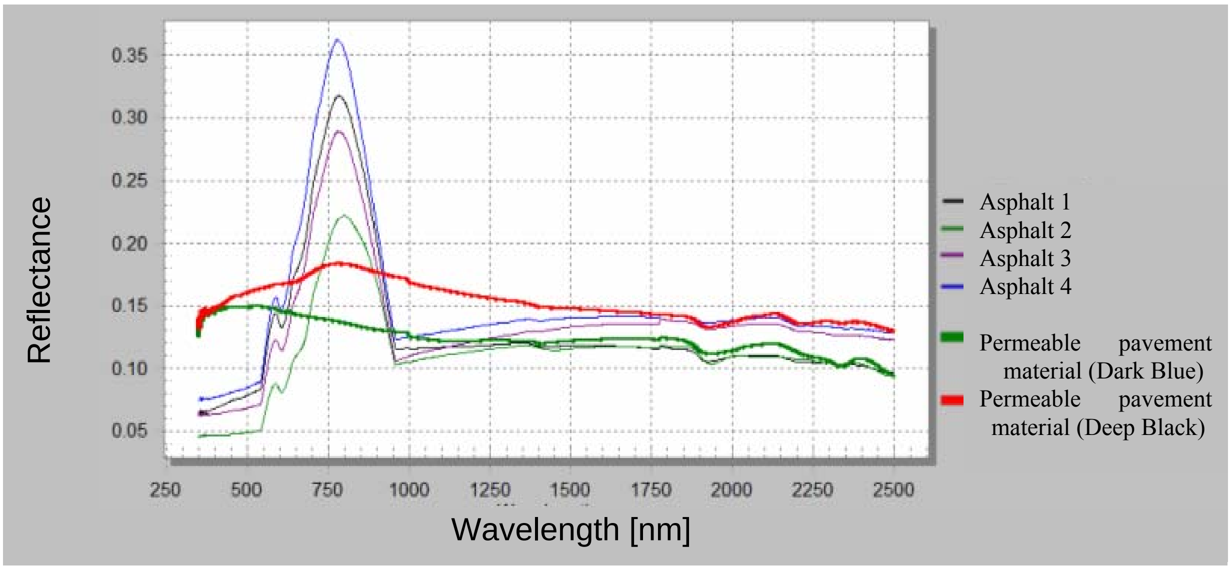

Figure 3. Spectra of road surface materials

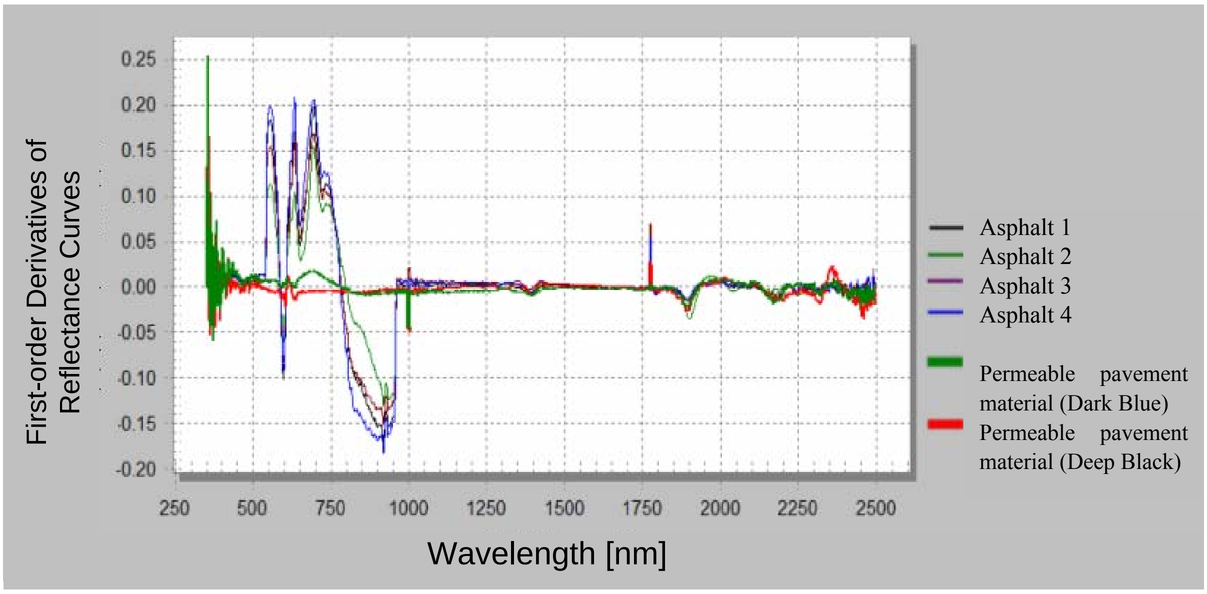

Figure 4. First-order derivatives of spectral reflectance curves of road surface materials

comparatively easy, but further examination is necessary to see if more detailed classification is possible.

6. CONCLUSIONS AND FUTURE WORK

6.1 Conclusions

The spectral reflectance library of construction materials was acquired with a ground-based spectrometer, and the possibility of classification of respective materials based on the spectral characteristics was examined in order to practically classify surface materials and land-cover in urban areas by the airborne remote sensing technique concerning the roof materials of buildings and road surface materials.

As a result, the spectral reflectance of most roof materials and pavement materials showed some differences in the values and the shapes of reflectance spectra in this study, and appropriate selection of spectral characteristics may permit classification of building materials commonly used in Japan, based on the spectral information.

6.2 Future work

The future assignments will include (1) experiment with an airborne sensor and (2) development of an advanced classification method using various data in combination.

6.2.1 Experiment with airborne sensor: In this study, a ground-based spectrometer was used to measure the spectral reflectance of construction materials under an ideal lighting condition. Meanwhile when a sensor mounted on an airplane is used for similar observation, the absorption and diffusion of light due to water vapor and fine particles in the atmosphere, as well as the temporal variation of the light condition, is expected to substantially change the apparent spectra even if the observed subject is one and the same. To cope with such a phenomenon, it is necessary to conduct observation and experiment with an airborne sensor to evaluate the atmospheric influence and then select an optimum method of atmospheric correction, thereby establishing a method to ensure aircraft observation for high-accuracy estimation of spectral reflectance characteristics of spatial objects.

6.2.2 Establishment of an analysis method using various data in combination: Landscape assessment of urban areas requires comprehensive examination of geometrical information, historical and cultural background information, and many other types of information, in addition to the information obtainable from spectral data. In addition to airborne hyperspectral or multispectral remote sensing, airborne laser scanning and GIS-based spatial analysis of related geographical information are expected to permit advanced collection of data for multilateral assessment of the landscapes of urban areas.

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