

'Identification of Construction Materials Using High Resolution Satellite Images for Assessing Building Vulnerability'



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Abstract

Disaster management and planning activities in urban areas require information on building vulnerability, which in turn depends directly on the construction materials used. Traditional land survey methods for assessing the construction materials used in buildings and other man made structures are expensive and time intensive.

This paper elaborates the use of a new methodology of using very high-resolution images, like IKONOS and Quick Bird (resolution of 1m and 0.61 m respectively) for differentiating various construction materials used. The case study aims at establishing the relationship between the man-made features and the construction materials used, based on the basic elements of image interpretations. Thumb rules, for identifying and assessing the building materials from the high-resolution images, were also established and are highlighted in this paper.

As part of the research to differentiate building vulnerability, a study about the height, width and length of the buildings were also inferred, which in turn are the factors controlling the vulnerability of buildings to hazards like earthquake and fire.

The study revealed that through satellite image interpretation, a number of construction material classes such as Concrete, Asphalt, Stone, Cemented Tiles, Asbestos, PVC/Plastic roofs, Teflon, Mud-Tiles and Bricked Houses, Mud-Tiles and Muddy Houses, and Steel in Bridges can be identified.

Introduction

Vulnerability mapping is done through conventional field surveys. With the advent of modern technologies such as satellite remote sensing and aerial photogrammetry, the disaster mapping has become considerably easy. Especially, the high-resolution satellite data, viz., IKONOS and Quick Bird images have opened up a new era in risk mapping. Although such images are normally interpreted for typical land use/ land cover mapping, here the authors have tried to assess and interpret a new aspect i.e., the identification of construction material of buildings, from these images in order to assess the vulnerability of the buildings. Attempt here has been made to interpret it through the construction materials used in the building rooftop as guide to the complete structure. This information helps in regional risk/damage assessment studies and provides a valuable input to the risk models in very quick turn-around-time.

Remote Sensing for Risk Management – History:

Data derived from remote sensing techniques are widely used as one of the inputs for many of the models created for assessing the risk factors. Traditionally medium resolution landuse\landcover data (at 30m, 25m or 15m) with different vulnerability/roughness value assigned to it are used for the assessment of probable risk in a region. Any of the present models lacks remote sensing data derived at building level.

Hyper-spectral images are theoretically designed to give information about the individual construction materials constituting the buildings. However, any attempt to assess the building material using hyper-spectral images, are currently in infant stage and proof of concept in this regard needs to be established.

The complexity in identification of construction materials through remote sensing was envisaged by many researchers. Welch (1982) explained that the Urban landscapes are composed of diverse materials such as concrete, asphalt, metal, plastic, glass, shingles, etc, arranged by humans in complex ways by building housing, transportation systems, utilities, commercial buildings and recreational landscapes. In the similar fashion, Hornstra et al (1999) felt that the Urban areas are typified by intricate mixtures of materials ranging from concrete, wood, tiles, bitumen, metal, sand, and stone. The Spatial distribution of these materials is not regular and is compounded by rapid temporal changes that occur in the urban landscape over a very short period of time. Besides they have a high object density that leads to errors in the multi-spectral classification

It can be deduced from the earlier research, that even the reflectance of a particular material may vary in different sets of images, depending upon the sun angle, sun illumination condition, weather condition, dust particle in the atmosphere etc. Relative position of buildings in urban areas may also give different reflectance for the same kind of material used in two different buildings. Therefore, pixel-based methods of image classification cannot work successfully using such imagery, because such classifications assign each pixel to one or the other construction material category, solely based on the basis of its spectral reflectance properties.

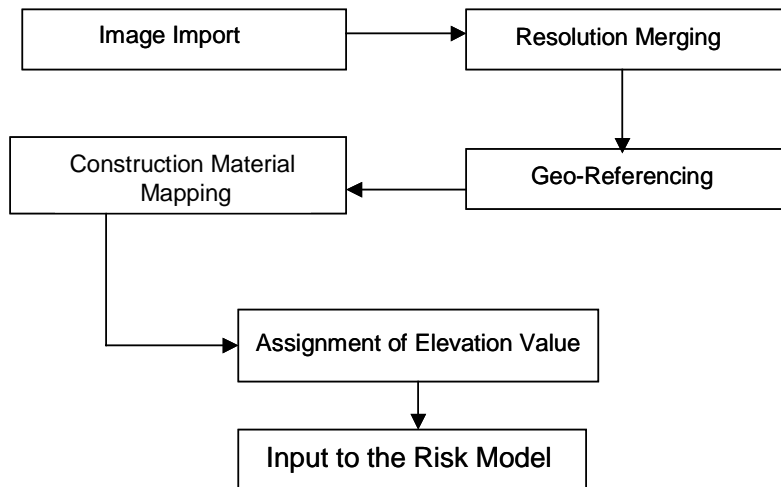
High Resolution Images for Vulnerability Mapping:

It has been observed that there is a relationship between the shape, size colour, etc., of the various man-made features and the materials that might have been used for its construction. A background knowledge of the common building materials used in the construction of different kinds of built-ups gives a fair amount of idea to assess the building material that might have been used in a particular set of building. In developing nations there also exist a direct relationship between the height of the building and its vulnerability. All such relationships of colour, size, shape and associations were difficult to establish using medium resolution images. With the advent of high- resolution images such as IKONOS and QuickBird with resolution of 1m and .61 meters respectively, such relationship of colour, size, shape and association can be established at ease in order to assess the building material over a large area in a short span of time. Any such high-resolution off-nadir satellite image captured at an angle ranging from 18-23 degree can also be utilized to deduce the relative/absolute height (Number of storeys) of the building, which in turn reflects the vulnerability of the building to various kinds of hazards such as earthquake & fire.

Authors, with above technique, have made an attempt to identify urban details such as low-, medium-, and high-residential buildings, Multi-storied building, commercial blocks, industrial buildings, Hotels, Go-down (Dumping yard), Sport complex, Stadiums, Tents, Forts, Tomb, Minarets etc. on the off nadir High Resolution Satellite Images (HRSI).

Flow Chart:

The chart below shows the general methodology involved-



Common Construction Materials Used:

A particular set of construction material is generally used in the construction of a particular type of building. Majority of the construction materials in a particular set depends upon whether they are Traditional/Old building or Modern/New building. The following paragraph shows the common set of construction material in the different building types-

- i) Traditional/Old Buildings-

- a) Residential Houses- Brick, Asphalt-Shingles, Lime, Slate, Stone, Asbestos, Tin, Steel Sheet, Mud, Mud-tiles, Concrete, Timber, Thatch, Bamboo etc.
 - b) Forts/Palaces/Minarets- Slate, Stone (Marble, Sandstone, Quartzite, Granite, Thick Brick, Iron) etc.
 - c) Roads/Bridges- Morang, Stone, Asphalt (Pitch, Tar), Timber, Ropes, Iron, Steel-Rod.
- ii) Modern/New Buildings-
- a) Residential Houses- Concrete, Brick, Asbestos, Tin, Steel-sheet, Teflon, PVC, etc.
 - b) Apartments/Shopping Malls/Sport Complex/Commercial Plazas- Concrete, Bricks, Ceramic Tiles, Stone Tiles, Cement Tiles, Glass Materials, PVC, Steel etc.
 - c) Roads/Bridges- Asphalt (Pitch, Tar), Concrete, Steel-Rods, Steel-wire etc.

Study Area:

Since the objective of the study was to identify the different kind of construction materials, the study was not done for a specific area. However to get variety of construction material in single image, QuickBird image of Mecca city at 0.61m was primarily used to identify the various types of building and assess the building material. Mecca, being a historic, religious and developing city is a place with ancient mosques & houses to modern architectural buildings. QuickBird image of Chennai was used to map the construction materials (QuickBird image courtesy: www.Digitalglobe.com).

Figure below shows the different construction materials assessed using QuickBird image-



Interpretational keys For Assessing The Building Materials:

Based on the study, various kinds of construction types and rules for assessing the building materials were evolved. JPGs showing various construction materials type in different buildings have been placed as different figures in Plate-1 (given at the end of this paper).

1. Concrete-

- a) Building with medium to high-rise, in most of the cases will be made -up of concrete material.
- b) If the roofs of such buildings are flat then the roof will also be made up of concrete.

- c) Colour of building or roof of such buildings may vary from different shades of white to different shades of brown.

Refer figures below, Plate 1 (Yellow rings)

2. Asphalt-

- a) Roads in the urban areas with shades of brown, will be made of asphalt
- b) Parking lots with dark shade of brown will also be made up of asphalt.

Refer figures- 8 and 6, Plate 1 (Yellow rings)

3. Stone-

- a) Any fort or old palace or ancient architectural buildings are most likely to be made up of Stone slabs. Commonly used rock types used as construction material are Granite, Marble, Sandstone and Quartzite.
- b) All these rocks have high reflectance value however granite and marble appear bright yellowish white or whitish in satellite image. Quartzite also appears bright whitish, however sandstone appears in varied color. Red sandstone is the most common building rock type.

Refer figures- 2 & 15, Plate 1 (Red ring and Red Polygon)

4. Cemented Tiles-

- a) Roofs of residential houses are some times made up of colored cemented tiles of different colors. Orange-brown is one of the popular colors. These roofs are generally slanted.

Refer figure- 3, Plate 1 (Blue ring)

5. Asbestos-

- a) Large factories or ware- houses often have slanting roofs, made up of asbestos or tin. The new tin roofs are usually marked by high reflectance, but with the passage of time the reflectance of tin also becomes low and comparable to the asbestos. Generally, they have a brown/buff color.

Refer figure- 7, Plate 1 (Yellow ring)

6. PVC/Plastic Roofs-

- a) Modern Indoor Stadiums and Plazas some times use PVC/Plastic to maintain the natural light within a building. They are usually colorless or bluish in color.

Refer figure- 6, Plate 1 (Blue ring)

7. Teflon-

- a) To give shelter to large number of people for some small duration, tents are the best option. Traditionally tents were made of linen. However this leads to casualties in case of fire. Modern tents are made up of Teflon or similar fireproof linen. They are identified on the satellite image due to high reflectance value, peculiar shape and close settings of other tents.

Refer figures- 9, 10 & 11, Plate 1 (Blue rings)

8. Mud-Tiles and Brick Houses

- a) Many medium sized residential houses have slanting roofs made up of brown/reddish-brown tiles. By seeing the size of the houses, it can also be inferred that the houses will be made up of 'bricks'.

Refer figure- 12, Plate 1 (Yellow polygons)

9. Mud-Tiles/Muddy Houses-

- a) Many small sized residential houses have slanting roofs made up of brown/reddish-brown tiles. By seeing the size of the houses, it can also be inferred that the houses will be made up of 'mud or thatch'.

Refer figure- 13, Plate 1 (Yellow polygons)

10. Steel in Bridges

- a) It is very easy to identify a bridge/flyover on a high-resolution imagery. By seeing the higher reflectance, it can be assessed that the material in it will be metal, preferably steel.

Refer figure- 14, Plate 1 (Yellow polygons)

Advantages of Study:

1. Building level data can be generated.
2. Building Vulnerability mapping for a large area can be done in relatively small span of time.
3. Such input will increase the accuracy of the risk forecasting models and help in Disaster planning and mitigation.
4. This kind of data will be very helpful for those involved in risk related business or insurance sector.

Limitations:

1. Vulnerability study using High Resolution images are supposed to be more useful in ancient cities and/or cities of underdeveloped and developing nations.
2. In few cases construction material may not be properly assessed simply based on the type of the buildings.
3. Paucity and restrictions of high-resolution images is the biggest limitation.

Conclusion:

The above study reveals that the high resolution images are found to be very useful in identification of the various building types such as residential, commercial, single dwelling, multi-storeyed building, shopping complex, bridges, tunnel etc. This in turn can be used in assessing the construction material that might have been used in such buildings. Information on height of the building will be an added advantage to assess the vulnerability of a particular kind of building to a particular kind of hazard.

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