[Slide 2]
Hello, my name is Michael Eguchi and I am an engineer at ImageCat who was involved with development of the exposure database for the METEOR project. This presentation will introduce the basics of exposure development. I'll go over the heuristic evaluations of construction patterns for generating a level 1 exposure database. Such topics will include identifying sources for categorization of structural types and materials, mapping to a given building taxonomy, and ultimately creation of the mapping schemes for Level 1 exposure.

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Exposure development first begins with identifying the local materials and structural systems common for the region. Construction practices will vary from country to country for a number of reasons: availability of materials, variations in traditional construction techniques, development and enforcement (or lack of) a national building code, etc. The slide identifies a few of the main categories, as well as some examples, of sources that should be tracked for this process. The availability of these sources will vary per country, and will often require some basic knowledge of materials and engineering topics.

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We typically first do a literature review to pull any existing documents on country specific and structural specific construction practices. These types of reports will not be available for every unique structural type within the country, however for those that are available, they provide some valuable insight. Such sources include EERI, World Housing Encyclopedia, PAGER, GEM, etc. Google scholar can be helpful in these situations. These reports are generally very detailed, and will often identify where in the country the structural type is found, typical heights, structural systems for lateral and gravity loads, foundations, common deficiencies, and other building attributes. The downside is these reports are often limited, and lack diversity of structural types and geographic regions.

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We then look for any county specific statistics. We've identified most countries have publicly available census and housing data that can be sourced. We found the most useful part of these data, are the regional breakdowns of wall, roof and flooring material. Most of the time these are broken out into rural and urban regions, however some countries will publish the statistics at a finer resolution. While specifics regarding the lateral system are not included, understanding what materials are being used, and in what region, will allow us to infer the structural system based on our previous research and observations. This type of data is useful for preliminary development of mapping schemes and general quality control checks.

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National building codes may or may not be available for every country. If they are available, we can determine the country specific construction practices, materials, detailing, and other structural requirements for code compliant design. Interpreting

the code to determine the buildings strength, ductility, stiffness, deficiencies and other structural properties will require some technical and engineering background. One main issue is that, even with an established building code adopted, construction can often be unregulated, and what is proposed in the code will often not be found in the field, so one should be a bit wary of automatically assigning a vulnerability to a specific structural type found in the code. General code adoption and compliance should be researched beforehand.

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User submitted and online imagery are the most common types of information available for exposure development. Streetview imagery through sources such as google, mapillary, online videos or geotagged photos allow us to visually identify the building attributes such as number of stories, occupancy, structural system in some instances. Using streetview and satellite imagery also allows us to identify general correlations between roof shapes (gable or hip), roofing materials (tile, built-up, thatch) and wall materials. Where streetview is not available, particularly in rural regions, these correlations will be useful in inferring a structural system. Occasionally a building under construction will be visible via ground imagery, which can help determine the lateral system involved. Submitted photos or videos often give an interior view and will reveal some information not visible behind the exterior façade. Post disaster photos or videos will often reveal exposed building materials and failed structural systems. A number of online imagery sources can be helpful with structural designation determinations.

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The previous sources should give the analyst a general understanding of the types of structural materials used, types of roofing materials used and types of structural systems applicable. The next step is to find the distribution of construction types based on the built-up development patterns. The table here provides a sample of the structural distributions for rural regions, and are categorized for the PAGER taxonomy. These can be mapped to other taxonomies, such as GEM, when required.

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The following slides will give a general summary of how to determine the country-specific construction types and structural distribution for any given country. Here we present Bangladesh as an example. The first step is to do a web search to identify the structural types unique to the region. Here, we've sourced engineering journals, WHE reports, seismic vulnerability assessments, country-wide risk assessments and other reports. This gives us a general overview of some of the predominant structural types within the country.

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To identify other structural types not specifically listed in research articles, we turn to census data. Two examples are shown here. The first is the PAGER database which identifies distributions for 4 occupancies (rural residential, rural non-residential, urban residential and urban non-residential). As you can see the information is often

limited with only 4 construction types identified. The second is from a housing census which breaks out wall, roof and flooring materials for urban and rural regions. We ultimately use these as a starting point for creation of the mapping schemes. First we need to map census descriptions to a taxonomy we can use for vulnerability modelling. Based on the research previously done, we know what types of materials/systems to expect, therefore we can assign a best-fit structural type, which is shown in the last table. For example, when the census lists brick as a wall material, we can differentiate whether they mean sun dried, fired brick, concrete block or other masonry types.

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Using ground photos via user submitted or streetview we can verify that our structural assumptions are correct.

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For Bangladesh we identified six unique development patterns seen here: rural, primarily single-family residential, high density residential, urban, high urban and industrial regions. A satellite image of each development pattern can be found on the right.

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To develop the distribution of structural types for each development pattern, we use the resources previously discussed. Mapping schemes for two of the development patterns, rural and urban, have already been established through the housing census data. These percentages are sanity checked through visual observations of satellite imagery and ground photos.

For single-family residential development patterns, we worked off the rural mapping schemes and adjusted the distributions as we saw fit. For example, we observed a fairly significant increase in concrete with masonry infill homes and a decrease in the more traditional construction methodologies such as mud, wood-framed and informal construction. We observe these changes through visual inspection of satellite imagery. We take note of things such as the types, colors and shapes of the roof, and what structural type we can expect given these observations. We observe the size of the building footprint, which generally increases from rural to single-family, and take note of what structural types to expect for the increase in size. We then verify our assumptions with imagery found in geotagged photos or streetview imagery. We then adjust the percentage breakouts of the rural mapping scheme based on these observations.

For high-density residential, urban and high urban development patterns, we first evaluate the height profiles. We observed predominately low-rise structures in high-density residential regions, low to mid-rise structures in urban regions and mid to high-rise structures in high urban regions. With a few exceptions, these height profiles will be typical for most countries. Using these height profiles, we can start making assumptions regarding particular structural types. For example, for mid to high rise structures we can assume traditional techniques using local materials are no longer applicable, and have been replaced by concrete frame with URM infill, or perhaps engineered reinforced concrete frame or shear wall structures. For low-rise structures, similar to rural and single-family development patterns, we observe roof and building footprint characteristics and verify our assumptions with ground imagery. For Bangladesh we observed a mix between fired brick masonry and masonry infill, with some informal construction in the high-density residential regions. For each development pattern we adjust the percentages based on these visual observations.

For industrial development patterns, we first observe the height profile, which was exclusively low-rise. We then determined the footprint profiles within the development pattern. For example, is it predominately open warehouse with large footprints? Is it only a few warehouses with supporting offices? We observed a mix of both for Bangladesh. We then use ground imagery to determine what structural system is common for both the warehouse and the surrounding structures and calculate the distribution accordingly.

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After going through all the processes, we ultimately end up with mapping schemes like the one shown here. Each development pattern has its own unique set of structural distributions. Once completed, the first question is to ask if the results make sense. For example, do we see a lessening of traditional techniques the more urban the development pattern gets. Do we see the expected height profiles for each development pattern? We would expect taller buildings in the central business districts and gradually decrease the further out you get. Oblique photos such as the one shown are available and can be a quick check to determine whether the preliminary assessments are reasonable. Do these mapping schemes represent the built-up environment throughout the country? For example, is the urban development pattern applicable in all regions. We can then sanity check the results through a sampling strategy for each development pattern. The resultant statistics will confirm whether our initial assumptions are correct, or whether they will need to be finetuned.

I hope the presentation provided you with an understanding of the heuristic evaluations of construction patterns for generating a level 1 exposure database. In the report, we presented an example for Bangladesh, however the same processes can be molded to fit any other country of interest.