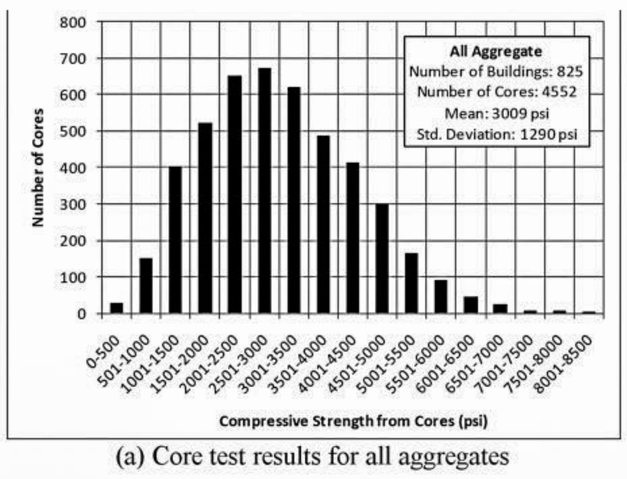
TABLE I
COLOR CODES BASED ON FOS OF COLUMNS ALONG WITH REQUIRED ACTIONS WITHIN TIME FRAME STRUCTURAL ASSESSMENT OF BUILDINGS HOUSING RMG FACTORIES

Factor of Safety (FOS) of column	Color codes	Description	Actions with Time frame
Below 1.25	Red	Critical visible defects resulting in immediate danger to structure and workers.	Require Detailed Engineering Assessment (DEA) along with core test immediately
Between 1.50 and 1.25	Amber	Significant visible defects with no immediate danger to structure or workers.	Require DEA along with core test within six weeks
Between 1.86 and 1.5	Yellow	Limited visible defects with no immediate danger to structure or workers.	Require actions and core test within 6 months
Better than 1.86	Green	No critical visible defects or structures and no visible immediate risks to workers.	No immediate actions required.

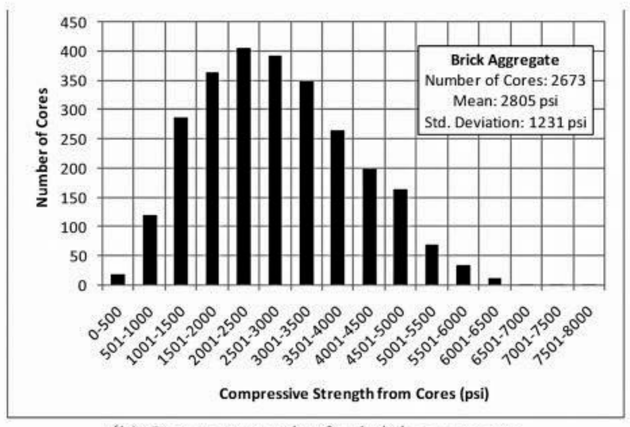
Findings from RMG Factory Buildings' Structural Assessments

Starting from June 2013 until February 2015, 4552 core samples of 825 factory buildings were collected and tested at BUET's Concrete Laboratory, among which 2673 samples are of brick aggregate and 1823 are of stone aggregate. Out of these 825 factory buildings, 12 are built before 1980, 198 are built between 1980 and 2000 and the rest after 2010. Approximately, 52% of those factory buildings are constructed after 2005. Figure 2 shows distribution of these core test results for all aggregates, stone aggregates and brick aggregates along with number of sample cores for the tests, and mean and standard deviation of strengths found from the tests. For overall all the aggregate samples, the mean and standard deviation of strength are 3009 psi (20.8 MPa) and 1290 psi (8.9 MPa) respectively. For brick aggregate sample cores, the mean and standard deviation of strength are 2805 psi (19.3 MPa) and 1231 psi (8.5 MPa) respectively. For stone aggregate sample cores, the mean and standard deviation of strength are 3312 psi (22.8 MPa) and 1320 psi (9.1 MPa) respectively.

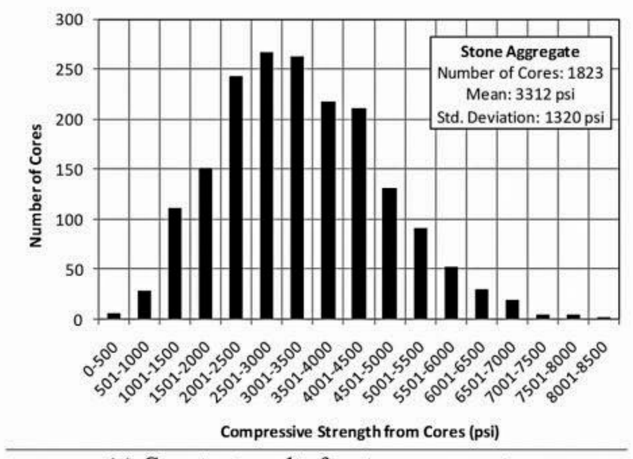
Detail Engineering Assessment (DEA) is required to have in-depth understanding of the condition of the structure. It also identifies inadequate structural members (if any) with respect to capacity as per code. In addition to that the condition of the structure can be assessed for different loading conditions. As per Alliance, Accord, and NTC guideline (NTPA, 2013), DEA is required if the visual or initial assessment found structural distress in main load-carrying members, apparently inadequate



(a) Core test results for all aggregates



(b) Core test results for brick aggregate



(c) Core test results for stone aggregates

Fig. 2 Core tests performed at BUET between 2013 and 2015

main structural members for both vertical and lateral load, or extension beyond design drawing or permission. Accord and Alliance have published their own protocol regarding DEA. The typical Steps for the assessment are shown below. The steps may vary according to the level of assessment and information available.

- Prepare As-built Architectural and Structural drawings, if not available already. The as-built drawing shall show the structural, non-structural elements with dimensions at all levels, foundations and framing on plan, section and elevation, and cross-sectional drawings showing reinforcements in foundations, columns, beams, slabs etc. If as-built drawings are available - verify if it truly represents the structure. As-built drawing shall be prepared/ checked as per NTC Guideline (NTPA, 2013).
- Scanning of reinforcement bars in main structural elements of lower tiers to confirm as-built condition.
- Confirm bar size by drilling 50mmx 50mm holes at rebar location.
- Arrange confirmatory soil test (2 to 3 borings).
- Spot check of foundation by excavation, if necessary.
- Identify causes of any physical distress, dampness or any other abnormalities and suggest remedial measures.
- Work on specific items of concern identified in the initial structural assessment report
- Identify any overloading, additions, extensions, presence of water tanks, towers. Study their effect on the structure and suggest remedial measures.
- Arrange for core test by taking 4 Nos. 3 inch cores (preferably from columns) to assess in situ strength ensuring sample reliability, testing of cores in approved laboratories only, and proper interpretation of core test results considering various factors as per ASTM C42-90.
- Use ACI 562 to find equivalent concrete strength to be used in design checking
- UPV tests may also be conducted with proper calibration.
- Prepare structural model as per As-built drawing using appropriate software by following the standard practice and building code.
- Obtain reliable data on steel grade or arrange testing of steel rebar (if possible) or assume 40 grades conservatively for using in all analysis/design adequacies.
- Use loading and Load factors as per standard (NTPA, 2013).
- Check strength and serviceability requirements as per Bangladesh National Building Code (BNBC, 1993).
- Make recommendation(s) based on results of DEA- including restriction of loading, restriction on vertical extension.
- In case of deficiency in structural integrity of the structure(s), appropriate retrofitting scheme is to be designed.
- Prepare Load Plan and arrange posting of load plan and approve it.
- Submit report for review by the Engineering Team

Retrofitting is the modification of existing structures to make them more resistant and safe. In case of factory buildings, retrofitting will have to be carried out as per the DEA. The DEA of factory buildings will incorporate a full structural evaluation of the building, as well as investigation of ways to improve the factory buildings based on several defining criteria. In case of retrofitting, the requirements of BNBC are to be adhered to as much as possible, although it recognized that in some cases a fair judgment must be made as to how much a building can be improved based on its existing condition, as well as how economical it will be to satisfy every design criteria as stipulated by code requirements. The overall strategy will be generally as follows based on a hierarchical principle of increasing compromises:

a) Follow strictly the code design requirements to assess the actual deficiency of the building under analysis.

b) Determine all possible requirements, and which compliant factors can be relaxed in order to achieve a minimum level of compliance of another factor which does not comply (for example, the relaxation of floor loading in order to achieve a reasonable level of punching shear resistance when taking into account lateral loads which cause unbalanced forces within the structural system)

c) Propose a comprehensive remedial plan based on the extent of works and the practicality of carrying them out cost-effectively. Prepare alternative retrofitting schemes to remedy the structural deficiency. Discuss with the owner about construction issues and cost. Decide the most optimum retrofitting option.

d) Submit Retrofitting Scheme for review by the Assessment Team.

e) Supervise retrofitting work during construction for quality control and certify the structural integrity/safety after construction as per the provision of the Remediation and Oversight Protocol.

In some cases, situation may arise at which the results of the analysis may have the possibility of rendering certain buildings completely unfit for purpose, and the extent of remedial works may be too much and too complicated to implement. In such cases, it should be decided whether or not partial or complete demolition and reconstruction should be considered as a single viable option.

There is no denying that Bangladesh has progressed a lot since three years after Rana Plaza collapse in terms of achieving workplace safety compliance issues in RMG industry, under three plans of actions - National Tripartite Action Plan (NTPA), the European Union Sustainability Compact, and the United States Trade Representative (USTR) Plan of Action. Among 25 commitments under the National Tripartite Plan of Action on Fire Safety and Structural Integrity (NTPA), 16 have been fully or substantially completed and nine have been partly completed. Among a total of twenty nine listed activities in the EU Sustainability Compact, 15 actions have been fully or substantially completed, 13 actions have been partly completed, and one action regarding encourage retailers and brands to adopt and follow a unified factory audit code of conduct in Bangladesh has not been initiated yet. The United States Trade Representative (USTR) proposed a sixteen-point action plan, where substantial progress has been made in regards to twelve of the actions and greater progress is required in regards to four actions.

In all three plans of actions, structural assessments of buildings housing RMG factories have been given importance, with regard to which substantial progress has been made, i.e. up gradation of Chief Inspector of Factories and Establishment office to DIFE, sanction of 679 new staff positions including 392 new, organization of training program for capacity building of the newly recruited inspectors, development of Guidelines for Assessment of Structural Integrity and Fire and Safety including harmonized standards, establishment of a review panel along with a review mechanism to handle urgent safety issues in garment factories, initiation of assessments of the structural integrity and fire safety of RMG factory buildings, and creation of publicly accessible database of all RMG factories as a platform for reporting labour, fire and building inspections.

On the other hand, structural assessment alone is not enough to ensure a safe working environment for all in the sector. The weak factory buildings are required to be strengthened to ensure resilience through different initiatives, i.e. preparation on Corrective Action Plan based on the assessment findings, Detailed Engineering Assessment as proposed in the initial assessment report, and retrofitting as requirement. The Accord and the Alliance have showed much progress in preparation of CAP, but no CAP has been prepared under National Initiative so far. So, immediate actions are required by NTC to address the issues.

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