2021 SDC - Retrofit Deliverable

Part 1: Retrofit Implementation and Performance Assessment

After determining a structural design for the hospital addition and running a preliminary analysis, you decide that the existing structure should be retrofitted. Even if you determine that the existing members do not completely fail after adding the extension, you decide that it would be beneficial to increase the capacity of the hospital beyond code minimum because it is a critical structure after an earthquake.

1. Before adding a retrofit, determine if your structure with the extension performs well. To perform well, all individual members within the structure should pass the demand/capacity checks using the NDS methodology established in Deliverable 2 and all inter-story drift ratios should be less than 5% for all time history analyses considered in Deliverable 2. If the structure with the addition still performs well, identify the most critical members and the stories with peak inter-story drift ratios. If the structure with the addition performs poorly, what types of failure occur within the building? How does the performance of the structure with the addition compare to the performance of the existing structure before the addition?

2. Propose an appropriate retrofit scheme based on the failure modes identified in problem one. Aim to establish a retrofit scheme that results in all members satisfying the NDS demand/capacity member checks and reduces all drift ratios to less than 5%. If failure doesn't occur in your structure with the addition, propose a retrofit scheme that will reduce stress on the most critical members and reduce the largest inter-story drift ratios. Keep the following points in mind when designing retrofits:
    a. The retrofit scheme implemented in your balsa wood model should simulate retrofits that are used in real structures. Conduct research for typical retrofit strategies given your failure mode and utilize the discussion that you provide in part 2, question 2 of this deliverable when selecting your retrofit for the balsa wood model. You may consider retrofits that are applicable to wood, steel, and/or concrete structures. Please provide justification for how your balsa wood model retrofit relates to a full scale structure. You are not required to model a full scale structure or a full scale retrofit. An explanation of the selected retrofit that shows conceptual understanding of the related full scale retrofit is adequate.
    b. For the retrofit, you may deviate from the balsa wood material properties and member sections specified in Deliverable 2, but only with strong reasoning for how deviation from the specifications is applicable to a real retrofit of a full scale structure. Any deviation should be reasonable and adjustments in material properties and section sizes should be within close proximity to those used in Deliverable 2. Clearly state if you choose to stray from the Deliverable 2

guidelines for material and section properties and justify this decision by describing how the adjustment affects the performance of your model.

c. Loading requirements, floor plan requirements, and maximum floor plan dimensions must follow the requirements specified in sections 5, 6, and 7 of the Deliverable 2 Design Guide.
d. You are permitted to adjust the structural addition above the existing structure from the original design proposed in Deliverable 2 to account for the new retrofit of the existing structure. However, we ask that the addition conforms to all aspects of the Deliverable 2 Design Guide and doesn't deviate from the specified material and section properties.
e. Consider the architectural and economic implications of your proposed retrofit. The retrofit should have minimal impact on the functioning of the hospital and on the architectural design. Alternatively, consider how the retrofit scheme can be incorporated into the architectural design. The cost of your retrofit should be qualitatively taken into account based on the type and total amount of material used.
f. Clearly state any assumptions or simplifications you make when designing your retrofits.
g. Accurately provide the final weight of the structure and the total rentable/utilized floor areas after the retrofit. Your reported values will be checked against your provided model and/or drawings. A penalty of 30 *V* will be applied in case of 5% or more difference between the actual and reported values.

3. Provide any calculations that are important in showing the effectiveness of your proposed retrofit. Consider how the critical member demand/capacity ratios and inter-story drift ratios reduce with the addition of the retrofit.

4. Use diagrams and drawings to illustrate how your balsa wood retrofit scheme is implemented in the existing balsa wood structure. Also illustrate any changes to the extension design.

5. In addition to the deliverable submission, we ask that you also submit the ETABS or SAP2000 file of your final retrofitted model so that the analysis results recorded in your deliverable submission can be checked and verified.

6. ***BONUS QUESTION*** In your structural design submission from Deliverable 2, you were asked to use flexible diaphragms for the existing building. Now, change your assumption from flexible diaphragm to rigid diaphragm for the existing building only. Compare the mode shapes of the building (with extension) incorporating flexible diaphragms in the existing building portion with the mode shapes incorporating rigid

diaphragms in existing building portion of the building (with extension). Pick three floor levels, one at the top of the extension (roof of the building with extension), one at the top of the existing building, and one at the middle of the existing building (6th floor). Analyze the mode shapes visually in plan view for these three floors, and comment whether you see any difference. If you see any difference, do you think you would have to retrofit different elements/parts of the building if rigid diaphragms were used in the existing building? No calculations need to be reported for this part. However, you can report the graphic (snapshot) comparison of mode shapes in plan view for this part to support your comments.

Part 2: Retrofit Conceptual Questions

1. The probability of collapse at a specified earthquake hazard level can be calculated as a ratio of number of earthquake scenarios resulting in a collapse relative to the total number of scenarios considered. According to the ASCE-7 guidelines, the maximum limit for the collapse risk is 1% in 50-years. Suppose that the probability of collapse (Pc) for the existing hospital with the addition is 0, 0.05, 0.11, and 0.25 for 100-yr, 475-yr, 975-yr and 2475-year hazard return periods (Tr), respectively.

   First, calculate the 50-year collapse risk. If the code-recommended target value is not achieved, retrofit is necessary to meet the code requirements. A suitable retrofit strategy would reduce the probability of collapse at each hazard level.

   You may follow the below steps to calculate the 50-year collapse risk:

   a. First, the annualized collapse risk (λc) should be calculated by combining collapse fragility and the seismic hazard curve as shown below.

   $$\lambda c = \sum_{i=1}^{n} \frac{(Pc_i + Pc_{i+1})}{2} * \left| \frac{1}{Tr_i} - \frac{1}{Tr_{i+1}} \right|$$

   Where, Pc_i is the collapse probability at hazard return period of Tr_i. Note that n is equal to three in this case.

   b. Second, the 50-year collapse risk (x) can be calculated by assuming the Poisson distribution of the probability of collapse as shown below.

   $$x = 1 - exp(-50 * \lambda c)$$

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After computing the 50-year collapse risk, determine the minimum reduction factor (m) that can be applied to all collapse probabilities as a result of the retrofit scheme in order to meet the target collapse risk (1% in 50-years). For example, if the reduction factor (m) is 1.5, all collapse probabilities should be divided by 1.5. Note that (m) can be any real number greater than 1.

2. What types of retrofit techniques could be used for a concrete building, and for a steel building? List several common techniques and provide brief descriptions separately for these types of buildings. If there are techniques that can be applied to both, also discuss them. For this question, provide a brief explanation for two real-world retrofit examples that have been performed successfully in your area or elsewhere.