Engineering Failure Analysis 82 (2017) 198–207

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Seismic behaviour of the old-type gravity load designed deteriorated RC buildings in Cyprus

Ismail Safkan[a,*], Serhan Sensoy[a], Zehra Cagnan[b]

[a] Department of Civil Engineering, Eastern Mediterranean University, via Mersin 10, Turkey
[b] TED University, Ankara, Turkey

ARTICLE INFO

Keywords:
Corrosion
Material degradation
Aging effects
Concrete strength
Cyprus

ABSTRACT

Corrosion related deterioration of reinforced concrete buildings is often studied by the structural engineering community. The literature reveals the fact that modelling of deteriorated members requires a unique consideration due to brittle section behaviour. The late adaptation of seismic regulation rules and lack of decent quality construction material supply results a vulnerable building category in the island of Cyprus. This paper examines the vulnerable building category by combining concrete strength variation with different corrosion levels. A common building type representing 1980's was selected for analyses. By using the experimental data on local materials, the corrosion rate and concrete strength specific models were generated. The analyses on brittle low strength deteriorated models yielded to a reduction both in strength and ductility. The effects of considering different concrete strength on non-seismically designed deteriorated buildings were discussed herein.

1. Introduction

It is widely accepted and observed fact that corrosion results in deterioration of reinforced concrete buildings. Especially at pre-code period the inadequately washed sea side supplied aggregates with high chloride contamination lead to a decrease in strength which is further leading to a reduction in life expectancy of the corresponding structure.

Low strength concrete dominates the older reinforced concrete type buildings where proper concrete mix facilities did not exist. A recent study [1] shows the significance of the concrete strength when bond and shear failure modes are considered in modelling. Bonding between concrete and the reinforcing steel plays an important role on global earthquake performance of the structure. The smooth reinforcement dominates the gravity load designed buildings in Cyprus. As studied by others the slip deformation can contribute to large displacements of sections with smooth reinforcing steel [2–4]. Also it is often observed that in case of an inadequate confinement and anchorage length the bond failure may dominate the strength and ductility of the sections with smooth reinforcement [5–6].

Recent studies [7–9] on assessment of deteriorated buildings demonstrated that the corroded buildings face significant seismic performance reductions. The literature reveals the fact that corrosion results not only in the geometric size reduction of the reinforcement but in reduction of the ultimate bonding strength, cover strength degradation and degradation of the mechanical behaviour of the reinforcing steel material as well. The study by Berto et al. [7] considered the reduction of reinforcement diameter with a function of corrosion rate. The stirrup corrosion is also modelled by considering only the same amount of reduction in diameter and mechanical characteristics as longitudinal steel. Then, the three dimensional case study models were analysed by static

* Corresponding author.
E-mail address: ismail.safkan@cc.emu.edu.tr (I. Safkan).

http://dx.doi.org/10.1016/j.engfailanal.2017.09.004
Received 13 May 2016; Received in revised form 12 September 2017; Accepted 13 September 2017
Available online 14 September 2017
1350-6307/

pushover method. In a similar study by Pitilakis [8] assessing aging effects on non-seismically designed European RC buildings by considering material and cover degradation. Likewise a research conducted by Yalciner et al. [9], assessed an old type RC building by modelling the corrosion effects by taking into account the reduction in geometric size of the reinforcements, cover degradation and the bond stress reduction due to corrosion. However there is no specific research on poorly confined and lightly reinforced old-type reinforced concrete buildings suffering low strength concrete and poor detailing effects such as stirrup hook opening, buckling phenomena of the compression steel etc. Discounting these detailing effects may lead to an unconservative assumption when assessing the old type reinforced concrete buildings facing aging effects.

The main objective of this study is to investigate the direct relation of the concrete strength and corrosion effects on the global structural response of gravity load designed deteriorated buildings in Cyprus. The analytical models were generated by considering the advance constitutive laws available in the literature and the locally investigated material statistics. The results allow specifying the condition where the parameters dominate the brittle global structural response. Based on the detailed local material data as well as effect of corrosion on bond-slip, shear and cover strength reduction, mechanical properties and buckling phenomena of reinforcement steel were considered when modelling the moment curvature relationships for the corroded reinforced concrete buildings. This study highlights the effect of considering advanced corrosion modelling rules on seismic performance assessment of the gravity load designed reinforced concrete buildings based on concrete strength data in Northern Cyprus.

2. Building stock in Cyprus

The first seismic provision of Turkey, the Turkish Earthquake Code 1975 [10], was available for use but the local authority only demanded its use for the high rise buildings. Later in 1992 “The Seismic Detailing Provisions” [11] was published by the local Chamber of Civil Engineers where the structural detailing rules were legislated for all building classes in Northern Cyprus. However these detailing rules did not ask for a comprehensive base shear calculation and were limited to the minimum longitudinal steel diameter, minimum steel ratio, minimum stirrup spacing etc. Similarly in the same period of time, sea-side supplied concrete aggregates were prohibited and ready mix concrete was started to be used. This study concentrates on the pre-1992 period mid-rise building stock for which aggressive corrosion attack exists.

The corrosion related degradations are so far considered to be reduction in compressive strength of concrete, reduction in bond strength, flexural strength reduction due to decreased longitudinal bar diameter, and the mechanical degradation of steel reinforcement. The following framework was developed by the authors who assessed the effect of concrete strength on corroded old type building models. (See Fig. 1)

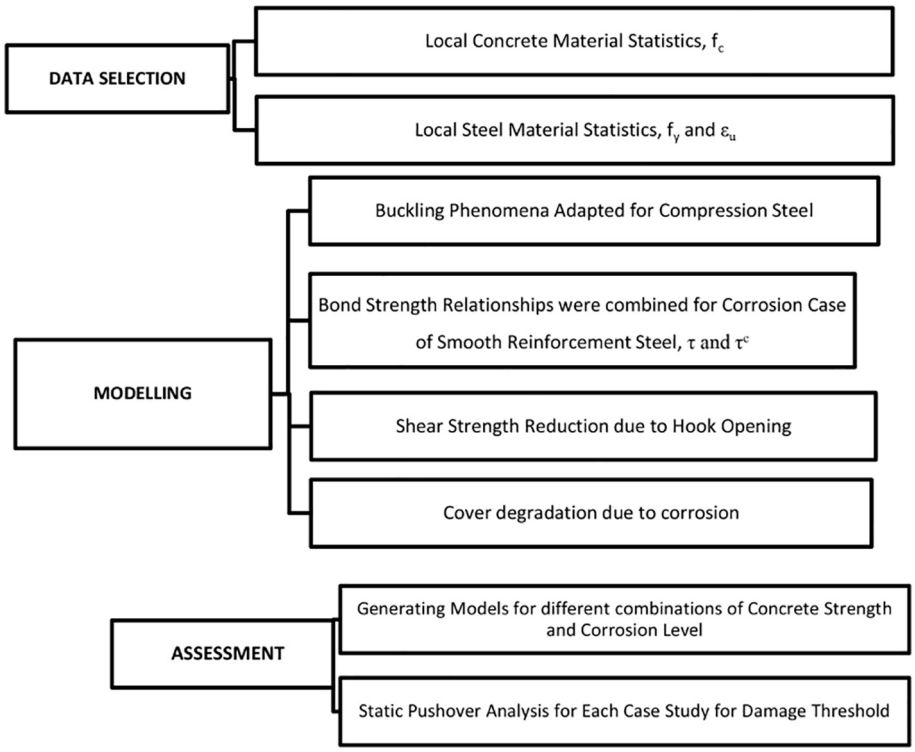

Fig. 1. The study framework.