Contents

Acknowledgments **vii**

Abstract **xiii**

Resumen (Spanish abstract) **xv**

List of Figures **xxi**

List of Tables **xxiii**

List of Symbols **xxv**

1 Introduction **1**
1.1 Background . . . 2
1.2 Problem statement, gaps and topic justification . . . 4
1.3 Research aim . . . 6
1.4 Research questions . . . 7
1.5 Research objectives . . . 7
1.6 Scope and limitations . . . 8
1.7 Probable outcome . . . 8
1.8 Thesis structure . . . 9

2 Literature review **11**
2.1 Overview of outdoor thermal comfort studies worldwide . . . 12
2.2 Aim of the review . . . 20
2.3 Review methodology . . . 20
2.4 Discussion of the results obtained . . . 22
2.4.1 The focus of the reviewed studies . . . 22
2.4.2 Study of built environment . . . 23
2.4.3 Micro meteorological measurements . . . 24
2.4.4 Use of software and its validation . . . 25
2.4.5 Thermal comfort indices . . . 25
2.4.6 On-site questionnaire survey . . . 28
2.4.7 Thermal comfort evaluation parameters and measurement scales . . . 30
2.4.8 Acclimatization and adaptation . . . 33
2.4.9 Thermal neutrality . . . 33
2.4.10 Effect of physical and climatic parameters on thermal comfort . . . 35
2.5 Gaps, limitations and future scope . . . 38

2.6 Summary . . . 41

3 Materials and Methods 45
3.1 Flowchart of the study . . . 46
3.2 Study areas selection . . . 47
3.2.1 Site at composite climate zone . . . 47
3.2.2 Site at hot and dry climate zone . . . 49
3.3 Morphological character . . . 51

4 Field study 57
4.1 User survey . . . 58
4.2 Climate of the site . . . 59
4.3 Micro-meteorological measurements . . . 60
4.4 Thermal comfort indices . . . 62

5 Numerical simulations and validation 65
5.1 Numerical simulations . . . 66
5.1.1 Selection of software . . . 66
5.1.2 Model development . . . 66
5.1.3 Climatic input . . . 68
5.1.4 Input parameters . . . 68
5.2 Validation . . . 70

6 Results and discussion 73
6.1 Results of User survey . . . 74
6.1.1 User survey results of Delhi study . . . 74
6.1.2 User survey results of Jaisalmer study . . . 76
6.2 Simulation Results . . . 78
6.2.1 Spatial and temporal variation of T_a, T_{mrt}, and PET at Delhi . . . 78
6.2.2 Spatial and temporal variation of T_a, T_{mrt}, and PET at Jaisalmer . . . 82
6.3 Effect of physical and climatic parameters on thermal comfort . . . 90
6.3.1 Effect of solar access on thermal comfort . . . 90
6.3.2 Effect of geometrical parameters on thermal comfort . . . 93
6.3.3 Effect of wind on thermal comfort . . . 95

7 Conclusion 99
7.1 Objectives addressed in this study . . . 100
7.1.1 Objective 1 . . . 100
7.1.2 Objective 2 . . . 101
7.1.3 Objective 3 . . . 101
7.1.4 Objective 4 . . . 102
7.1.5 Objective 5 . . . 102
7.1.6 Objective 6 . . . 103
7.1.7 Objective 7 . . . 103
7.2 Limitations and future directions . . . 105
7.3 General research implications for future work . . . 108

Appendices 111

A On site survey **113**
A.1 Questionnaire used for Delhi study 114
A.2 Questionnaire used for Jaisalmer study 115

B Simulated output **117**

References **123**

List of Publications **139**