Fiber-reinforced polymer bars, as an alternative for steel bars, are widely used to overcome the corrosion problem especially under severe environmental conditions. In the present research, the soil nail system was physically modeled in the laboratory. Since bond stress and creep displacements of the GFRP nails are not well understood yet, the nail–grout and grout–soil interfaces were experimentally investigated simultaneously in a soil box. In the first step, the bond stress of the GFRP soil nails was studied through pullout tests. Subsequently, experimental creep tests were carried out under sustained loads which were equal to a fraction of ultimate pullout load. Furthermore, the effect of soil density and surcharge pressure on bond stress of both interfaces was evaluated. In addition, the ultimate bond strength of the nail–grout interface was measured by physical tests, and the grout could not move. Finally, the dependency of creep displacements on different load ratios and variable surcharge pressures was explored. The results clearly showed that the ultimate pullout load of the steel nail–grout interface with no surrounding soil was more than that of GFRP. The grout–soil bond stress was affected by the variation of soil density more than nail–grout and an almost linear relationship between soil unit weight and bond stress was observed at both the interfaces. Nevertheless, the increment rate of bond stress decreased with the growth in surcharge pressure at both interfaces. Moreover, creep tests displayed an interdependency of creep displacements at the interfaces and rate of reduction of creep displacements with the decrease in the surcharge pressure increment